JOINT INSTITUTE FOR MARINE OBSERVATIONS

ANNUAL REPORT

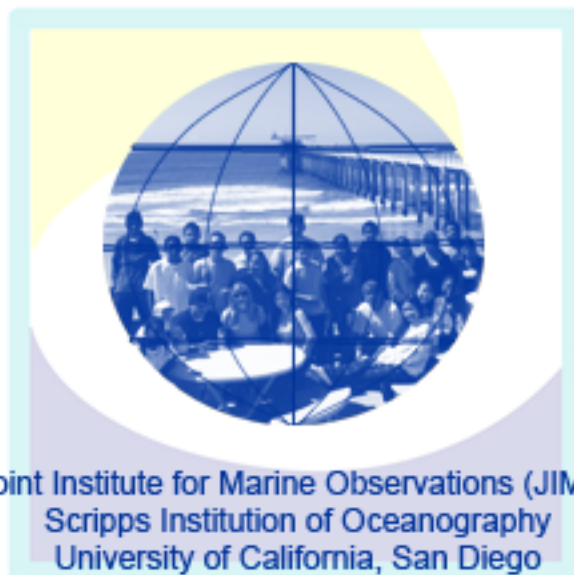## 2004-2005

Joint Institute for Marine Observations

UCSD

Joint Institute for Marine Observations (JIMO)
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JIMO's mission is to foster and enrich a center of excellence in which scientific research, education, and public outreach are joined to strengthen and improve our understanding of global ocean, climate, and earth sciences through individual and collaborative research.

INTRODUCTION

JIMO research and program activities for the fourth year (2004-2005) of the **National Oceanic and Atmospheric Administration** (NOAA) grant **NA17RJ1231** are outlined in this report. JIMO is affiliated with the **Scripps Institution of Oceanography** (SIO), a multi-disciplinary Institution for ocean, climate, earth and environmental research as part of the University of California, San Diego (UCSD) campus and greater University of California (UC) system. Included in this report are the individual projects, activities and accomplishments of JIMO researchers and partners at SIO and UC, as well as other collaborating organizations associated with JIMO.

JIMO's purpose is to facilitate and enhance research cooperation between NOAA entities and SIO, in particular, and the University of California (UC), in general, pertinent to the mission of NOAA. Initially, this mainly involved fostering existing NOAA-funded projects by SIO staff. As collaboration expanded, and opportunities grew, JIMO undertook facilitation of the work of many scientists outside SIO and began to develop new programs, and, at the same time, took advantage of its position within UC to employ the talents of an expanded constituency.

During the July 1, 2004 to June 30, 2005 period, the NOAA research entities listed below were engaged with SIO as part of JIMO in marine, atmospheric and climate research, disaster relief, and data collection collaborative activities:

o Office of Oceanic and Atmospheric Research (OAR)
o Office of Global Programs (OGP)
o Atlantic Oceanographic and Meteorological Laboratory (AOML)
o Pacific Marine Environmental Laboratory (PMEL)
o National Center for Environmental Prediction (NCEP)
o National Weather Service (NWS)
o Climate Data Center (CDC)
o Western Regional Climate Center (WRCC)
o Climate Prediction Center (CPC)
o National Marine Fisheries Service (NMFS)
o National Environmental Satellite, Data, and Information Service (NESDIS)
o Environmental Technology Laboratory (ETL)
o Climate Monitoring and Data Laboratory (CMDL)
o US Antarctic Marine Living Resources (AMLR)
o Forecast Systems Laboratory (FSL)
o Office of Ocean Exploration (OE)
o National Underwater Research Program (NURP)
o Pacific Fisheries Environmental Laboratory (PFEL)
o Climate Diagnostics Center (CDC)
o Coastal Ocean Program (COP)
o Coastal Service Center (CSC)
o Weather & Air Quality (WAQ)
o National Geodetic Service (NGS)

ORGANIZATION

Mission Statement

JIMO's mission is to foster and enrich a center of excellence in which scientific research, education, and public outreach are joined to strengthen and improve our understanding of global ocean, climate, and earth sciences through individual and collaborative research.

Vision Statement

JIMO shares the fundamental mission and goals of NOAA research and strives to achieve several objectives based on the unique resources and character of the Scripps Institution of Oceanography (SIO), in particular, and University of California (UC), in general: (1) to foster collaborative research between NOAA and UC scientists; (2) to facilitate participation of UC and other academic scientists in NOAA programs; and (3) to use the educational strength of UC both to train students for productive work in environmental activities and to educate the citizenry about the intellectual excitement and importance of studying and managing our environment.

The current Memorandum of Understanding (MOU) between NOAA and SIO that outlines the purpose, goals and structure of JIMO is the original established in 1991. In this agreement, plans for an Executive Board and Council were set, but a Council was never appointed. As this MOU marked the first Joint Institute at SIO, the anticipated role of a Council was replaced by natural interactions of JIMO members already immersed in the highly collaborative community existing at SIO. In practice, the need for scientific guidance or leadership was filled by open communication between JIMO Investigators (AKA "Fellows") and the JIMO Director, as well as other UC/SIO researchers or NOAA officials, on an "as needed" or case-specific basis. The same held true for the Executive Board, until 2005. In preparing for a programmatic and scientific Review by NOAA, JIMO sought leadership and advice from outside SIO. The Executive Board, consisting of the members listed below, met at SIO on **April 5, 2005**. This meeting yielded valuable advice that contributed to an overall positive review of the JIMO program by NOAA officials and the Review Panel. Reinforced by the Review Panel's recommendations, JIMO is committed to respond to its escalating growth with accelerated efforts to establish a governing body and strategic plan for the future. The role of the Executive Board, in particular, will become increasingly important, as JIMO plans to strengthen its role in NOAA collaborative research within the California region.

JIMO Executive Board Roster

Director:

Peter Niiler serves as the Director of JIMO and the head of JIMO's Executive Board. Dr. Niiler is currently a professor at the Scripps Institution of Oceanography and inventor of the "Global Drifter Program", which is the first global ocean observing system component to be completed in 2005. His research interests in the oceans are in circulation theory and observations, Lagrangian particle motions on continental shelf and development of autonomous instrumentation for ocean climate observations. He has his B.S. from Lehigh University (1960) and Ph.D. from Brown University (1964).

Board Members:

John Orcutt is Deputy Director for Research at Scripps Institution of Oceanography and Director of the UCSD Center for Earth Observations & Applications. He graduated from Annapolis (1966) and received his PhD in Earth Sciences from Scripps (1976). He is President of the American Geophysical Union (AGU) and was a member of the Science Advisory Panel to the Ocean Policy Commission. He was elected to the American Philosophical Society in 2002. His research interests are seismology and the use of information technology in integrating sensor networks; he has published more than 150 peer-reviewed papers.

Phillip Arkin is Deputy Director and Senior Research Scientist at the Earth System Science Interdisciplinary Center (ESSIC) of the University of Maryland. He helps to administer ESSIC and conducts research into the observation and analysis of precipitation and other aspects of the hydrological cycle of the global climate system. Until January 2002, he served as Program Manager for Climate Dynamics and Experimental Prediction in the Office of Global Programs at NOAA, where he managed the Applied Research Centers that provide the research and development that enable NOAA to provide better climate forecasts. From 1998-2000, he served as the Deputy Director of the International Research Institute for Climate Prediction (IRI) at Columbia University. He has spent the last 25 years working at NOAA as a research scientist and administrator in various parts of the climate community, including the Climate Prediction Center, the Office of Global Programs and the National Centers for Environmental Prediction. He invented the GOES Precipitation Index, a method for estimating rainfall from geostationary satellite observations, and led the Global Precipitation Climatology Project from 1985-1994. His B.S. in mathematics and M.S. and Ph.D. in meteorology are from the University of Maryland. Dr. Arkin has published more than 50 refereed papers in scientific journals, 22 atlases and chapters in books, and has had more than 100 non-refereed publications. He has served as a member of many national and international scientific panels, and has presented invited papers at more than 100 workshops and scientific meetings.

W. John Gould is currently serving as the International ARGO Project Director, as well as a Frohlich Fellow at CSIRO in Hobart, Australia. In addition to ARGO, Dr. Gould served as the appointed Director at both the International CLIVAR Project Office and the WOCE International Project Office. He possesses over 30 years of experience as an observational oceanographer and science project leader and over 20 years of experience managing science projects at a national and international level. He has served as chief scientist on more than 20 deep-sea oceanographic cruises. Receiving both his MS and PhD in Oceanography at the University College of North Wales, Bangor, Dr. Gould has received numerous awards and been published in dozens of significant, refereed publications during his career. His primary research interests include: The Role of the Oceans in Climate, North Atlantic Circulation, use of neutrally buoyant floats to explore ocean circulation, underwater acoustics, oceanographic and climate data management, and public understanding of science.
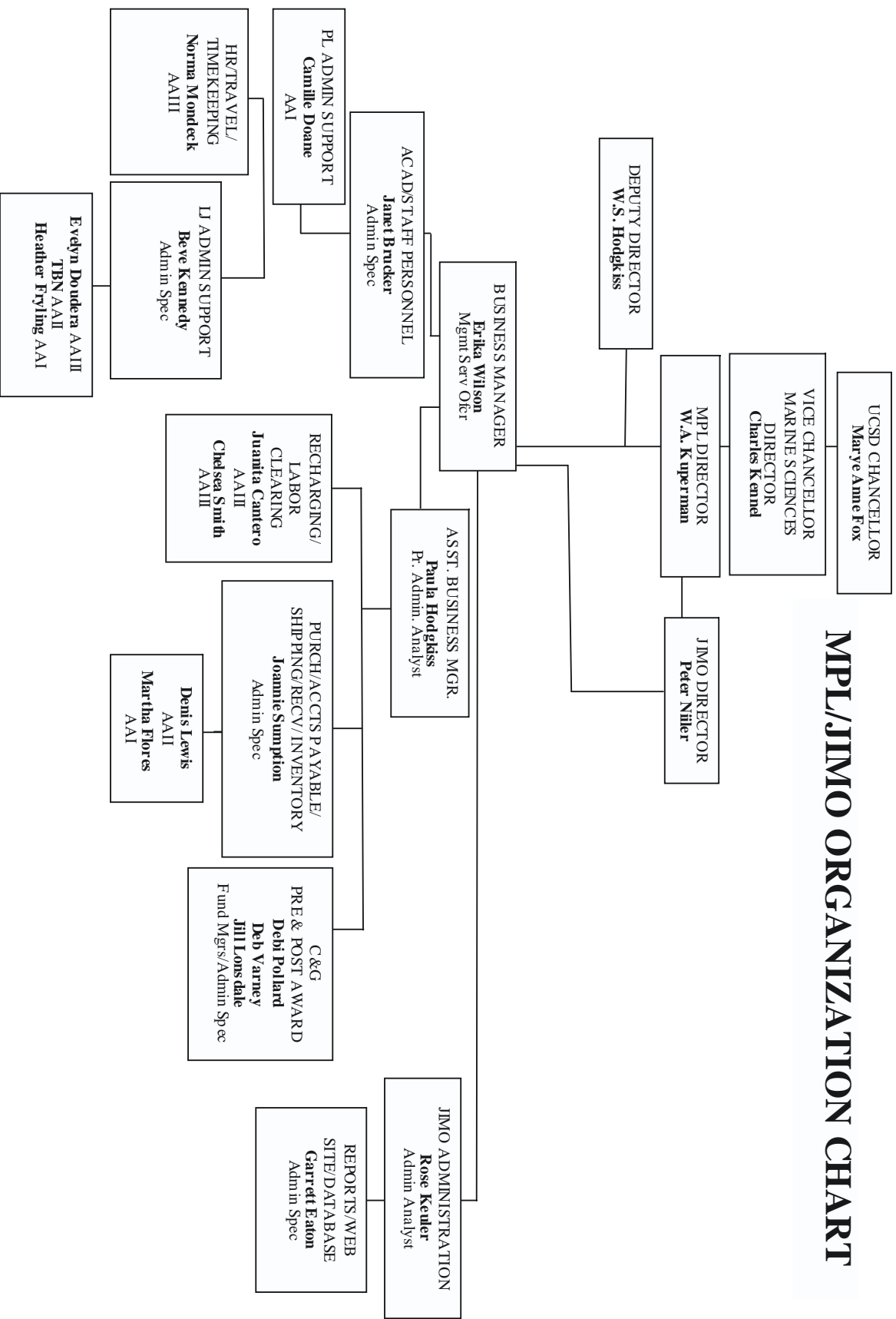
Kenneth Mooney has been Deputy Director of NOAA's Office of Global Programs (OGP) since 1994. Before that, he served as Program Manager and then Director of the U.S. TOGA Project Office. He is an experienced Oceanographer, working for both the NOAA Engineering Support Office and U.S. Coast Guard Oceanographic Unit. Dr. Mooney received his B.S. and M.S. in Physics from the Rensselaer Polytechnic Institute and University of Maryland, respectively, and his Ph.D. in Oceanography was conferred by the University of Rhode Island in 1977.

David B. Zilkoski has been employed by NOAA for over 30 years, serving currently as Acting Technical Director of the National Ocean Service and Interim NOAA Integrated Ocean Observing System (IOOS) Manager. He received a B.S. degree in Forest Engineering from the College of Environmental Science and Forestry at Syracuse University in 1974 and a M.S. degree in geodetic science from the Ohio State University in 1979. He has authored a number of publications on coastal subsidence, surveying, and vertical datum. Mr. Zilkoski is also a past President of the American Association for Geodetic Surveying, a member of the American Geophysical Union, Maryland Society of Surveyors, and a fellow of the American Congress on Surveying and Mapping and the International Association of Geodesy.

William Fox, current Director of the NOAA Southwest Fisheries Science Center, has a long history of exemplary leadership and service with NOAA. Since 1990, he has served as Director of NOAA Fisheries, the Office of Science and Technology, and Office of Protected Resources. Prior, Dr. Fox was a professor of marine biology and fisheries and Director of the Cooperative Institute for Marine and Atmospheric Studies at the University of Miami's Rosenstiel School of Marine and Atmospheric Science. Dr. Fox has authored or co-authored over 60 scientific publications. He is a member of the American Fisheries Society, a Fellow of the American Institute of Fishery Research Biologists and Sigma Xi--the Research Society. His formal education includes a B.S. in zoology (1967) and an M.S. in marine science (1970) from the University of Miami and a Ph.D. in fishery science (1972) from the University of Washington.

In addition to the Director and Board, JIMO is managed administratively through the Marine Physical Laboratory (MPL) of SIO. MPL possesses experienced administrators versed in the funding processes and policies of NOAA sponsored research. In addition, NOAA research dollars benefit from MPL's current negotiated overhead rate of 13%, as compared to the standard 54% rate of SIO/UCSD.

MPL/JIMO ORGANIZATION CHART

UCSD CHANCELLOR
Marye Anne Fox

VICE CHANCELLOR
MARINE SCIENCES
DIRECTOR
Charles Kennel

DEPUTY DIRECTOR
W.S. Hodgkiss

MPL DIRECTOR
W.A. Kuperman

JIMO DIRECTOR
Peter Niiler

BUSINESS MANAGER
Erika Wilson
Mgmt Serv Ofcr

ACAD/STAFF PERSONNEL
Janet Brucker
Admin Spec

PL ADMIN SUPPORT
Camille Doane
AAI

HR/TRAVEL/
TIMEKEEPING
Norma Mondeck
AAIII

LJ ADMIN SUPPORT
Beve Kennedy
Admin Spec

Evelyn Doudera AAIII
TBN AAII
Heather Fryling AAI

ASST. BUSINESS MGR.
Paula Hodgkiss
Pr. Admin. Analyst

RECHARGING/
LABOR
CLEARING
Juanita Cantero
AAIII
Chelsea Smith
AAIII

PURCH/ACCTS PAYABLE/
SHIPPING/RECV/INVENTORY
Joannie Sumption
Admin Spec

Denis Lewis
AAII
Martha Flores
AAI

C&G
PRE & POST AWARD
Debi Pollard
Jill Lonsdale
Fund Mgrs/Admin Spec

JIMO ADMINISTRATION
Rose Keuler
Admin Analyst

REPORTS/WEB
SITE/DATABASE
Garrett Eaton
Admin Spec

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JIMO Employee Summary (July 1, 2004 – June 30, 2005)

SIO Personnel Supported by NOAA/JIMO Funding				
Category	Number	B.S.	M.S.	Ph.D.
Associate Director	1			1
Academic Administrator	1			1
Project Scientist	2			2
Staff Research Associate	5	4	1	
Postdoctoral Fellow	6			6
Programmer/Analyst	7	4	2	1
Senior Coder	1	1		
Administrative Asst.	1			
Total (≥ 50% support)	**24**	**9**	**3**	**11**

Undergraduate Students	31			
Graduate Students	25	23	2	
Employees that receive < 50% NOAA Funding (not including students)	95			
Located at Lab (include name of lab)	0			
Obtained NOAA employment within the last year	0			

Subaward Demographics				
Graduate Students	26	10		
Undergraduate Students	-			
Employees that received ≤ 50% NOAA funding	16			
Obtained NOAA employment	14			
Personnel located at a NOAA lab	27	NOAA Santa Cruz lab,		
Support > 50%				
Laboratory Asst.	4	4		
Postdoctoral Fellows	4			4
Senior Research Associate	5	1	3	1

Current JIMO Fellows Roster

Peter Adams (UCSC)	Ralph Keeling (SIO)
Farooq Azam (SIO)	Robert Knox (SIO)
Timothy Barnett (SIO)	Lisa Levin (SIO)
Yehuda Bock (SIO)	Marc Mangel (UCSC)
Peter Bromirski (SIO)	Baldo Marinovic (UCSC)
Daniel Cayan (SIO)	Arthur Miller (SIO)
Christopher Charles (SIO)	B. Greg Mitchell (SIO)
Bruce Cornuelle (SIO)	Peter Niiler (SIO)
Russ Davis (SIO)	John Orcutt (SIO)
Edward Dever (SIO)	V. Ramanathan (SIO)
Andrew Dickson (SIO)	John Roads (SIO)
Neal Driscoll (SIO)	Dean Roemmich (SIO)
Peng Fang (SIO)	Daniel Rudnick (SIO)
Falk Feddersen (SIO)	Lynn Russell (SIO)
Reinhard E. Flick (SIO)	Uwe Send (SIO)
Peter Franks (SIO)	James Simpson (SIO)
Alexander Gershunov (SIO)	Susan Sogard (UCSC)
Ralf Goericke (SIO)	Richard Somerville (SIO)
Robert Guza (SIO)	Hubert Staudigel (SIO)
Konstantine Georgakakos (SIO)	Brad Tebo (SIO)
John Hildebrand (SIO)	Eric Terrill (SIO)
Osmund Holm-Hansen (SIO)	Elizabeth Venrick (SIO)
George Hunt (UCI)	Frank Vernon (SIO)
Jules Jaffe (SIO)	James Wilen (UC Davis)
Charles David Keeling (SIO)	Guang Zhang (SIO)
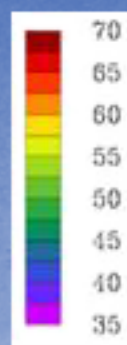
28°S
36°S
44°S
52°S

RESEARCH HIGHLIGHTS

JIMO research activities are categorized by the following themes:

A.   Climate and Coastal Observations, Analysis and Prediction Research
B.   Biological Systems Research
C.   Research in Extreme Environments
D.   R & D on Observations Systems

Research highlights, or Executive Summaries, of the most recent individual research projects are summarized in the tables below and are more fully developed in the body of this report.

A. Climate and Coastal Observations, Analysis and Prediction Research

Consortium on the Ocean's Role in Climate
[Russ Davis, SIO]

o As part of the Surface Velocity Program, 74 CORC drifters were deployed in the tropical Pacific. Enhanced observations in the Strait of Luzon include 40 CORC and 60 ONR drifters to study exchange between the western Pacific and South China Sea

o One hundred CORC drifters deployed in the North Pacific Equatorial Countercurrent were used, along with altimetry, to analyze the dynamics of that current. Zonal currents were found to be geostrophic but meridional currents are semi-geostrophic with acceleration of the zonal flow playing an important role. This effect has heretofore been disregarded in studies of variability in the region

o The CORC-developed Underway Conductivity Temperature and Depth (UCTD) is operational, allowing easy and safe operation on underway vessels

o A cruise in 2004, as part of the ONR-sponsored North Pacific Acoustics Laboratory (NPAL), included the first UCTD deployments by a group of users not involved in UCTD development. The results were encouraging. Over 170 casts were completed with only one lost probe. At this loss rate, UCTD cost per cast will be comparable to that of XBTs. Operations continued on the third NPAL cruise

o Analysis of 15 years of autonomous float data, including CORC SOLO floats, produced basin-wide maps of absolute mean velocity at intermediate depths in the South Pacific and Indian Oceans

o The CORC data assimilation model for the tropical Pacific is now using, in addition to altimetry, satellite SST and climatological T and S, most tropical Pacific data sets including TAO, drifters, CTDs, XBTs, CORC and Argo profiling floats, QuikSCAT winds and Greg Johnson's analysis of mean currents. Error covariances for all these new data were developed and tested

Consortium on the Ocean's Role in Climate—Abrupt Climate Change Studies (ARCHES) [Peter Niiler, SIO] [Various Investigators, LDEO, WHOI, U. of Maine, CEFAS]	o	Refer to CICAR 2004-05 Annual Report
Global Drifter Program (GDP) [Peter Niiler, SIO]	o	Supervised the construction of 1175 drifters and delivered for deployment to AOML. In July 25, 1209 drifters were reporting data from the global ocean
	o	In September 2005 the global drifter array will have over 1250 elements, making it the first global ocean observing system to be completely implemented
	o	Built and rigged for air deployment a 23 containers, with 39 drifters, into Atlantic hurricane 'Frances'. All 23 containers survived deployment from C-130
	o	Distributed enhanced global drifter data sets to 16 international and national science investigators
The Argo Project: Global Ocean Observations for Understanding and Prediction of Climate Variability (A coordinated project) [Dean Roemmich, SIO] [Russ Davis, SIO]	o	Demonstrated the ability of profiling floats to directly measure the mid-depth circulation of the global oceans using WOCE and Argo floats (Davis, 2005, Lavender et al, 2005)
	o	Improved design and production of SOLO/Argo floats leading to greater instrument reliability and lifetime, lead by the Scripps Instrument Development Group, under R. Davis
	o	Reached a total of 275 active SIO floats in the Argo program by mid-2005 out of an international total of 1922 Argo floats. Argo is now a global array, and is approaching completion
	o	Continued SIO collaboration with UW and NIWA/NZ to deploy over 200 Argo floats in the Pacific Ocean by NIWA's R/V Kaharoa
Scripps Experimental Climate Prediction Center (ECPC) (A coordinated project) [John Roads, SIO]	o	Upgrade of NCEP Global Seasonal Forecast Model
	o	Routine SFM seasonal forecasts furnished to IRI, NCEP
	o	Extensive forecast/analysis products provided to international CEOP model archives
	o	Global and Regional Coupled Ocean Atmosphere Model and upgrade of Regional Spectral Model
	o	Precipitation Assimilation
	o	Impact of surface water on regional simulations
	o	Fire Danger Predictions
Improved Cloud-Radiation and Hydrologic Cycle Parameterizations for Modeling and Predicting Climate Variability [Richard Somerville, SIO]	o	Identified several weaknesses in current ECPC Global Spectral Model (GSM)
	o	Evaluated physically advanced parameterizations in the single column model (SCM)
	o	Initiated implementation of improved cloud parameterizations in ECPC GSM
US and Global Water and Energy Budget Studies: A Contribution to CEOP [John Roads, SIO]	o	Provided Global Forecast/analysis products to international CEOP model archives using RII model and new SFM model
	o	Provided Regional simulations to international CEOP model archives and ICTS
Economic Benefits of Weather and Climate Forecasts to California Energy Production Management [Tim P. Barnett, SIO]	o	Identified the types of energy problems and decisions that could benefit from forecast information, including operational scheduling, electrical load forecasting, natural gas purchase planning decisions, and hydropower operational strategies

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	o Generated and communicated this information to energy partners, including the California Energy Commission, California Independent Systems Operator, San Diego Gas and Electric, and PacifiCorp
	o Integrated forecasts into operational models and other decision processes, for example with "delta breeze" forecasting for CalISO and "tariff day" scheduling with SDG&E
	o Evaluated the net economic benefit of forecast information; the total benefit of just the few projects we were able to address in the first year is conservatively estimated in the range of $5-$20M/yr. This valuation is that given by the stakeholders themselves of the value of this information
	o Conducted three case studies of the economic valuation of forecast information; the case studies include the "delta breeze", using ensemble forecast information, irrigation pump load forecasting, and forecasting peak electricity use days.
	o Analyzed effects of the NPO and ENSO on California temperatures. Gave these results to the California Energy Commission, which has charge of incorporating new forecast methods into guidelines for the state energy industry
	o Evaluated climate connections between California and the Pacific Northwest
Seasonal Climate Diagnostics Consortium [John Roads, SIO]	o Constructed a 3-month time series with a 3-hour interval from the 15-36 hour forecasts of each run of the NCEP Seasonal Forecasting Model (SFM)
	o Began comparison of regional simulation to the in situ observations and various global analyses
	o Generated and compared observations of precipitation in 7 global domains for both the regional spectral model (RSM) and Global Precipitation Climatology Centre (GPCC) data
IRI/ARCS Regional Modeling Applications Project [John Roads, SIO]	o Developed a new CVS version of the regional spectral model (RSM) to closely emulate the new Seasonal Forecast Model and this model was used for global change experiments
	o Continued development of a regional coupled atmospheric-ocean model in order to better understand air-sea interactions in the eastern North Pacific Ocean and California coastal region and eventually develop ocean applications
	o Continued fire danger predictions using myriad models, such as indices
SIO's Participation in US GODAE: Sustained Global Ocean State Estimation for Scientific and Practical Application [Dean Roemmich, SIO] [Bruce Cornuelle, SIO] [Russ Davis, SIO]	o Used a simplified (QG) regional data assimilation model of the central north Pacific to study the impact of Argo and XBT data on model results and to understand the limits of predictability of the mesoscale eddy field
	o Described interannual variability in northeast Pacific Ocean circulation using high resolution datasets (XBT and altimetry) together with a low resolution ocean data assimilation model (1o ECCO)
	o Completed the development of a scientific quality control system (GUI) for Argo profile (CTD) data, which was subsequently adopted by all international Argo partners, paving the way for research-quality Argo data for GODAE

Multi-column Continuous Flow Streamwise Thermal-Gradient CCN Chamber/Asian-Pacific CCN Network for Studying the Aerosol Indirect Effect [Greg Roberts, SIO] [V. Ramanathan, SIO]	o	Tested the single-column prototype instruments on several airborne and ground based measurements, including the 2004 NOAA/ICARTT (International Consortium for Atmospheric Research on Transport and Transformation) and ABC (Atmospheric Brown Cloud) Experiments
Global Model Investigation of Warm Season Precipitation for North American Monsoon Experiment [Guang Zhang, SIO]	o	Performed multi-year simulations of the North American Monsoon using NCAR CCM3 over the time period during which TRMM observations are available for comparison
	o	Systematically analyzed the evolution of the North American Monsoon system from CCM3 and its sensitivity to convection parameterization. Comparisons with observations from TRMM and gauge data are performed on timescales from seasonal evolution to diurnal variation
	o	Participated in the inter-model comparison activities through conference calls with PIs in GFDL and NASA
Evolution of ENSO and Tropical Pacific Climate [Christopher Charles, SIO]	o	Development underway of a comprehensive, high fidelity time series of ENSO, covering episodes of different global climate conditions
	o	High precision estimates of the variability of the tropical ocean over the last 1100 years
	o	Collection and dating of fossil coral specimens that constitute an unparalleled archive of variability in the tropical Pacific Ocean
Forecasting Climate Changes over North America from Predictions of Ocean Mixed Layer Anomalies in the Tropical and Mid-latitude Pacific [Arthur J. Miller, SIO]	o	The anomalous oceanic heat fluxes convergences in the KOE region lead to the changes in the transient eddies which is evident from the change of the location of the storm track locations over North Pacific
	o	Transient eddy forcing is crucial in maintaining mean atmospheric flow response to the low-frequency variability of the predictable oceanic heat flux divergence anomalies in North Pacific
California Applications Program (CAP) (A coordinated project) [Daniel R. Cayan, SIO]	o	Integrated documentary records of Western North America state, federal and Canadian large fires into a single large fire database for fire-climate research
	o	Identified differences between seasonal hydrologic structure in regions that are water limited and not water limited in the Western U.S. using surface energy/hydrology model simulation, particularly with respect to response to warming
	o	Assembled observations and global model simulation datasets to explore possible regional climate changes in California, with particular attention to impacts on hydrologic variability
	o	Continued work to develop and assess climate and hydrology ensemble prediction and reservoir management model system for northern and central California water resource management
Impact of Climate Variability on Sea Level Accelerations [Peter D. Bromirski, SIO] [Arthur J. Miller, SIO] [Reinhard E. Flick, SIO]	o	Modeled trends in relative sea level along the U.S. West Coast are about half those observed at vertically stable tide gauge stations
	o	Modeled interdecadal variability in sea level height (RSL) along the U.S. West Coast results primarily from variable wind stress forcing
	o	RSL is spatially coherent along the entire U.S. West Coast, but does not correlate well with either RSL across the interior of the northeast Pacific basin or with RSL at Hawaii

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North Pacific Climate Variability and Steller Sea Lion Ecology: Retrospective and Modeling Analysis [Arthur J. Miller, SIO] [Bruce Cornuelle, SIO]	o Found evidence for a climate-based mechanism in the decline of SSL in the Gulf of Alaska (GOA) post 1976-77 regime shift o Observed the presence of a distinct change in the ocean circulation of the Gulf of Alaska (GOA) after the 1976-77 climate shift occurred leading to increased eddy variance in the western GOA
Preparation and Analysis of an Extensive Historic Dataset of Ocean Carbon Dioxide Partial Pressure and Related Measurements [Charles D. Keeling, SIO]	o Continued to perform calculations of pCO2 from shore-based measurements of dissolved inorganic carbon o Search currently underway at SIO to assign a new PI after the passing of Dr. Keeling
CO2/CLIVAR Repeat Hydrography Program [Andrew G. Dickson, SIO]	o Attended meeting on data archival for this program, along with strategies of the design of new analytical equipment for the later stages of this program o Progress made ensuring SIO data is in the appropriate form for public release
Oceanic Measurements of Total Alkalinity [Andrew G. Dickson, SIO]	o Completed uncertainty analysis on measurement of alkalinity o Developed software for alkalinity titrations o Developed a spectrophotometric procedure for the measurement of alkalinity o Collected a wide variety of surface samples from around the world
Potential Application of Recent Collaborative Research Results to Operational Activities at the National Weather Service, Alaska Region [James J. Simpson, SIO]	o Selected by NWS as a Climate Partner. Two week residency program at NWS's new Climate Services Division and its Climate Predication Center, Washington, D.C. (January 17-31, 2004) o First high spatial resolution (1 km), long-term mean monthly climate analyses of Alaskan surface temperature and precipitation o Developed and validated end-to-end, satellite-based, high spatial resolution (1 km) and high temporal resolution (1 hr) retrievals of aerial extent of snow cover and insulation. Use of these new products in hydrologic basin models reduced the RMS error in modeled stream flow by 15% to 20% for the Sierra Nevada basins studied when compared against 1 minute in situ stream flow data supplied by USGS o Based on the Simpson et al., (2002) analyses / recommendations, NOAA HQ decided to fund / implement a "Test and Evaluate Volcanic Ash Coordination Tool" (VACT) at its Forecasting System Laboratory for subsequent operational use by NWS

B. Biological Systems Research

California Cooperative Oceanic Fisheries Investigations (CalCOFI) Time-Series and the Development of PaCOOS [Elizabeth Venrick, SIO] [Ralf Goericke, SIO]	o Continuation of a 55 year time series of physical, chemical and biological observations of the California Current ecosystem, with an emphasis on fisheries resources, and enhancement of the program with externally funded collaborations o Application of CalCOFI experience and expertise to the development of the Pacific Coast Ocean Observation System (PaCOOS)

Southern California Coastal Ocean Observing System (SCCOOS) [John Orcutt, SIO] [Russ Davis, SIO] [Eric Terrill, SIO]	o Launched first year of SCCOOS program, which will include a broad suite of observations that will be developed, deployed and maintained in the Southern California Coastal and Ocean region o Continued development of a nested ocean model that can operate at <500M resolution and will soon regularly produce time-dependent, three-dimensional maps of the velocity, ocean/air temperatures, and salinity. Future efforts include development and validation of routine modules for basic ecosystem state (nutrients, phytoplankton and zooplankton) and sediment transport o Began development of data management system to deliver real-time observations/modeling products in near real-time o Began development of user interfaces for data access to address specific data users: "General Public", "Engineering View", "Scientific Community", and "Decision Makers" o Initiated participation of scientists in a five week 5th grade science curriculum on climate that meets science standards and will be disseminated over the next three years to 16,000 students in Orange County, California
The Center for Stock Assessment Research (CSTAR) [Marc Mangel, UCSC]	o Increasing stock assessment capabilities nationally and internationally o Trained dozens of students and post docs in the CSTAR program in cutting-edge stock assessment techniques and analysis o Developed Bayesian methods for stock recruitment analysis in the case of a switch in the environmental regime o Completed first ever stock assessment of California sheephead
Genetic Population Structure of Central California Coastal Salmonid Populations [Susan Sogard, UCSC] [Gary Griggs, UCSC]	o Evaluated the population genetic structure of Chinook salmon from California coastal basins and was found to be consistent with current evolutionarily significant unit (ESU) designations and sufficient to allow genetic stock identification of all major populations o Genotyped trout above and below dams in the south-central and southern California ESUs and all were found to be part of the same coastal steelhead genetic lineage
Ocean and Estuarine Physiological Ecology of Salmon [Susan Sogard, UCSC] [Gary Griggs, UCSC]	o Determined that juvenile Chinook salmon from California's central valley export about 27 KJ of energy per fish as they exit the San Francisco estuary. They gain another 960 KJ over the next 9 months in the ocean o Discovered that steelhead in the central California coastal streams have differing spatial and temporal growth rates. Fish in upstream locales grew best in the winter and spring, whereas those in the estuary grew best during the summer and fall
Early Life History Studies in Rockfish [Susan Sogard, UCSC] [Gary Griggs, UCSC]	o Discovered that larval rockfishes differ among species in physical attributes at parturition and subsequent performance capabilities o Determined that species differences appear to be related to timing of parturition and oceanographic conditions

Groundfish Ecology Cruise Program [Pete Adams, UCSC]	o Collected data on 32,943 fish from 65 cruises, which are being used in current stock assessments o Developed age and growth parameters for the following species: sand sole, greenspotted rockfish, vermillion rockfish, starry flounder, and gopher rockfish o Developed fecundity estimates for greenspotted rockfish and rex sole
Cooperative Studies of Pacific Coast Salmon: NOAA Fisheries and the University of California, Santa Cruz [Pete Adams, UCSC]	o Conducted six field studies addressing population dynamics, food web interactions, life-history patterns, genetic structure, and fish-habitat relationships o Led NOAA Fisheries Technical Recovery Teams charged with developing scientific criteria to serve as a basis for ESA-listed salmonid species recovery plans o Served on NOAA Fisheries Biological Review Teams to review and update current status reviews for ESA-listed salmonid species, including chinook salmon, coho salmon and steelhead trout o Provided GIS (Geographical Information System) support for the technical recovery planning process of ESA-listed salmonid species and research-monitoring efforts. GIS products used to identify independent populations, potentially suitable habitat and connectivity among populations o Completed a documented list of streams within the Central California Coast Evolutionarily Significant Unit known or suspected of historically supporting coho salmon, and associated recent survey information, enabling analysis of trends in occupancy rates within the ESU o Developed a statistical model to estimate stream residence time of spawning coho salmon for improved escapement estimates using "area under the curve" methods, and evaluated the model using field data
Shipboard Monitoring of the California Current System Off Central California [Baldo Marinovic, UCSC] [Francisco Chavez, MBARI] [Curtis Collins, Naval Postgrad School]	o Continued quarterly shipboard measurements along central California in cooperation with NMFS o Took a variety of physical and biological measurements along Line 67 & 60 o Collected and analyzed chlorophyll-a and nutrients from the northern CalCOFI lines
Phytoplankton Studies in Cooperation with the U.S. Antarctic Marine Living Resources (AMLR) Program [Osmund Holm-Hansen, SIO] [Christopher Hewes, SIO]	o Sampled 195 stations in the Elephant and Shetland Islands area of the Southern Ocean for phytoplankton stocks, nutrient concentrations, dissolved organic carbon, and optical characteristics of the water column
Dynamics and Mechanics of HAB Dinoflagellate Mortality by Algicidal Bacteria [Peter JS Franks, SIO] [Farooq Azam, SIO]	o Designed and tested species-specific probe for algistatic bacterium ALC1 o Used probe in field samples to identify and locate bacterium ALC1 during L. polyedrum bloom o Determined that ALC1 released an extracellular serine protease in the medium to slow down L. polyedrum motility o Isolated 5 additional bacterial strains that cause motility loss and/or death of L. polyedrum
Climate-driven bottom-up processes and killer whale abundance as factors in Steller sea lion population trends in the Aleutian Islands. [George L. Hunt, Jr., UCI]	o Created volume of Fisheries Oceanography dedicated to the Aleutian marine ecosystem, highlighting research by this project. Volume includes 18 papers, with the major theme focusing on Samalga Pass discoveries o Discovered a striking ecological discontinuity at Samalga Pass (about 169 °W) that carries through the system from physics to marine birds and mammals

A Joint Program for Training and Research in Marine Resource Management Modeling [James E. Wilen, UCD] [Louis Botsford, UCD] [Alan Hastings, UCD]	○ Continued management modeling research and training, including acoustic tagging study of blue rockfish, sparse data methodology development for stock viability assessment, estimation of rockfish catchability curves, modeling voluntary bycatch reduction programs, examining self management by harvester cooperatives, and modeling biological and economic impacts of MPAs
Right Whale Studies in the Gulf of Alaska and Bering Sea [John Hildebrand, SIO]	○ Processed Acoustic Recording Package (ARP) recordings that provide new information on the occurrence of right whales in the southeast Bering Sea ○ Discovered that the acoustic environment in the southeast Bering Sea has enabled us to localize calling right whales at distances on the order of 10s to 100 km for ARPs and sonobuoys ○ Deployed 5 new ARP/HARPs in the Bering Sea and recorded right whale calls during a NOAA vessel-based survey off Kodiak Island (Gulf of Alaska) in 2004
Paired Oceanographic Whale Call Samples [John Hildebrand, SIO]	○ Sonobuoys used to locate right whales in the Bering Sea and study their calls ○ Two new high frequency acoustic recording packages deployed to study odontocetes off the coast of Washington
Measurement and Modeling Analysis of Organic Aerosol and Their Cloud Interactions [Lynn M. Russell, SIO]	○ Detected alkanes, alkenes, aromatic compounds, ammonia, nitrates, sulfates, organo-sulfur compounds, carbonyl and oxydril functional groups by using FTIR spectroscopy in atmospheric aerosol samples collected at Chebogue Point in Nova Scotia and aboard *R/V Ron Brown* ○ Saturated and unsaturated hydrocarbons show a fairly constant ratio on the *R/V Ron Brown*, with more variability and a stronger contribution from saturated compounds at Chebogue Point. The *R/V Ron Brown* samples also showed more carboxylic functional groups than the Chebogue Point data set
Exploring Vailulu'u Seamount: Bio-, Hydro-, and Lithosphere Interactions [Hubert Staudigel, SIO] [Brad Tebo, SIO]	○ Discovered a new volcano formed over the last four years, growing almost 300m ○ Explored a new Eel-based low temperature hydrothermal habitat ○ Detected a toxic moat surrounding the new volcano with mass fish mortality ○ Found new hydrothermal vents with the production of CO_2 drops

C. Research in Extreme Environments

Methane Seeps Under Hypoxia: Novel Ecosystems within Eastern Pacific Oxygen Minimum Zones [Lisa Levin, SIO]	○ Completed a 10-day cruise in the Gulf of California that did not yield methane seeps but strong influence of oxygen gradients was observed in the water column and benthos. Abundant sulfur bacteria within the oxygen minimum zone may play a key role in the Gulf ecosystems ○ Completed detailed surveys of several locations using ship-based sonar, video imaging by ROV, multicoring, trawling and dredging to assess sediment composition, bottom geophysical features, deep water and OMZ boundary layers, and biological populations ○ Performed outreach activities, including a multinational, multilingual expedition involving a broad range of scientists, nationalities, disciplines, and levels of expertise (from undergraduate and graduate students to senior scientists) ○ Initiated technology transfers across institutions involving the camera system and quick release technology used

D. R&D on Observations Systems

Joint Project Agreement Concerning the National Spatial Reference System in California [Yehuda Bock, SIO]	o Completed the San Joaquin Valley height modernization survey o Developed version 1.0 of the Pocket GPS Manager (PGM) o Used the PGM for a subsidence monitoring project in Yolo County o Expanded the Continuous GPS backbone (with PBO) and upgraded CGPS stations to real-time operations o Hosted a real-time networks symposium attended by over 70 participants
Implementation of a Real-Time Precipitable Water Capability Using the Global Positioning System [Yehuda Bock, SIO] [Peng Fang, SIO]	o Reliably running 48 hour long session (on a faster processor for the primary analysis) and 36 hour session (on a slower processor for the redundant analysis) as backup o Implemented longer orbit arcs improved the accuracy of predicted segment of the precise orbits o Introduced published (on web) NANU message based unhealthy satellite rejection in addition to broadcast embedded message based unhealthy satellite rejection and orbit overlap checking scheme
Participation in IT Infrastructure for the Future Study Group [James J. Simpson, SIO]	o Participated fully in all discussions and deliberations of the Study Group at the ORA facilities in Washington, D.C. to help formulate recommendations on new algorithm/systems and applications to be used in correlation with future data satellites and instrumentation systems used by NOAA/ORA o Formulated a list of recommendations on IT Infrastructure for ORA's future planning activities o Assisted the Group Leader and support contractor with writing the draft final report o Reviewing the draft final report, providing a written critique and finalizing the set of recommendations for ORA's consideration. The final report will be about 114 pages long. It contains a detailed rationale for all recommendations made

RESEARCH TASKS AND THEMES

Research Tasks

Under the Joint Institutes' cooperative agreement, five tasks are outlined by JIMO and agreed upon by NOAA, allowing JIMO to group and account for research more easily. The tasks are identified as follows:

Task 1. Administration
Task 1.1 funding is for administration of the Institute and includes support for the JIMO Director's office and minimal support for the staff. It includes costs associated with annual scientific meetings that are deemed important for the JIMO Director to attend, workshops sponsored by JIMO, web-site development and maintenance, funding for the Joint Institute Director's and administrative board meetings and formal review.

Task 1.2 is to support the postdoctoral fellows and graduate students, as well as provide a visiting fellows program. It is intended to be a very visible mission of this Institute. Funding will be provided based on merits of the researchers and applicability of interdisciplinary specialties that can be utilized across various JIMO projects.

Task 2. Joint NOAA Laboratory/JIMO Programs
The collaborative proposal has NOAA and UC/SIO working together jointly on research themes. These proposals are broken out by theme and include all research associated with funding including the funding of salaries, benefits, as well as instrumentation and computer time.

Task 3. Individual Science Projects
A cooperative research proposal is one which is specific to the JIMO theme areas, but is submitted by individual scientists of JIMO. The distinction here is that there is a loosely bound tie between individuals working on similar themes or topics. It is also seen that this may be a mechanism for developing collaborative proposals in the future, as well as encouraging new areas of research to develop. These proposals are broken out by theme and include all research associated funding including the funding of salaries, benefits, and instrumentation and computer time.

Task 4. JIMO Cooperative Research Programs with Other Research Institutions
In support of NOAA's Mission and Strategic Plan, JIMO's Task 4 was developed to strengthen and coordinate a University of California multi-campus environment by establishing a regional concept for marine and atmospheric sciences. Proposals would include research conducted at other University of California campuses, such as UC-Santa Cruz, as well as other academic institutions and non-profit research institutions, when appropriate, in support of JIMO and NOAA research missions, and in meeting NOAA's strategic goal of environmental stewardship. These proposals will include a program development cost (PDC) that will support the Visiting/Postdoctoral Fellows program at JIMO/SIO (Task 1.2).

Task 5. JIMO Research Infrastructure Proposals
Because proposals relevant to JIMO will be using a variety of observation platforms in order to carry out the research objectives, an infrastructure task by theme area was defined, which includes proposals for platform and specialized research facilities. We anticipate that a number of other agencies will be partners in support of the platform infrastructure.

Research Themes

Four thematic areas form the basis for research performed in partnership with NOAA. Each of these areas are relevant to the NOAA mission elements, particularly those of environmental assessment and prediction and environmental stewardship.

A.   Climate and Coastal Observations, Analysis, and Prediction Research

The primary goals for this research theme are to understand the remote forcing functions that control fundamental ocean and atmosphere processes and to utilize this knowledge for prediction. For JIMO the

basis of interest is primarily the Pacific, although other areas may be studied as a model or to put the Pacific information in context (e.g., Indian, Arctic). These thrust areas include the following:

Ocean observations will utilize many of the in-place observation systems such as the TAO/TRITON array, drifters, floats, and satellite remote sensing to provide information for models on climate prediction at the ENSO to decadal space and time scales. Defining the ocean's role in governing the climate necessitates the expansion of large-scale, long-term field observation and modeling efforts begun over the past few years in the Pacific to the global system. A networking of these programs in the UC to NOAA research projects is essential to the success of the effort. Deep ocean circulation constitutes another emphasis of this theme area that stresses the fundamental processes governing geochemical pathways. Deep ocean characterization, including deep-water formation and tracking that uses state-of-the-art floats and moorings, as well as unique observations and monitoring techniques, such as chemical or geochemical tracers for signature analysis. In addition, proxy data is used in providing the past climate variability.

Climate prediction and modeling are concerned with the development and evaluation of a wide range of climate models. Of interest are global atmospheric models, regional atmospheric models, global and basin ocean models, and land surface models concerned with surface hydrology and fire danger. The JIMO goal is to eventually develop coupled atmosphere, ocean and land models that provide greater predictability than is possible with current uncoupled models of these processes. Defining the limits of predictability for these systems requires extensive computational resources and collaborations with NOAA centers that are engaged in similar research efforts.

Coastal ocean assessment and forecasting seeks to measure and define the basic processes in the near-shore ocean (eddies, upwelling, currents) and atmosphere (fog, inversions, UV). Research is required to characterize the feedbacks between the coastal ocean and atmosphere and to assess the historical variability. The ultimate goal is to be able to perform short-term predictive modeling for such areas as natural hazards (oil spill), navigation and commercial recreation and the recruitment of pelagic stocks. Consideration must be given to mesoscale to small-scale processes and temporal scales of hours to decadal. The 70-year, daily SIO pier data and shore stations measurements, in situ moorings, stationary platforms, as well as aircraft and other remote sensing observations will be used to generate the necessary scientific data.

Atmosphere and ocean/atmosphere exchange will continue and strengthen research of mutual interest to SIO and NOAA scientists. These studies include: "teleconnections" and other large-scale meteorological phenomena; air-sea physical and chemical exchange processes; and global distributions and trends of climate-forcing due to anthropogenic and biogenic atmospheric trace gases and aerosols.

Biogeochemical cycles need to be further defined for their implications for global climate change. These include ocean, atmospheric and terrestrial components of the carbon cycle, oxygen cycle, UV chemistry, and trace metals among others. In addition, proxy data such as ice cores will be used to measure a wide array of paleo-climatologically important physical and chemical parameters such as the CO_2 content and isotopic composition of air recovered from bubbles trapped within the ice.

B.   Biological Systems Research

The population dynamics and physiological ecology of marine ecosystems is a complex research question, which involves finely tuned long-term observation programs. Process oriented research at the system and individual level lead to the fundamental understanding of the physiology and life cycle dynamics of important species. This theme area includes the following four thrust areas:

Fisheries research analyzes long-term trends of ecosystems and fisheries using databases such as the 55-year CalCOFI program, examines the schooling and behavior of selected species, develops new methods of stock assessment, and forecasts and investigates the effects of fishing activities on the environment. Food chain dynamics is of particular interest in the success of larval populations. Basic studies on the physiology and behavior of such species as sharks are of particular interest. Paleo-oceanographic techniques for the reconstruction of past distributions and abundances are necessary to help decipher the natural variability of the selected commercially important species.

Marine ecosystem monitoring and forecasting examines the distribution and abundance of organisms at all levels of the food chain in relation to their environment, primarily the physical and chemical structure. Ocean currents as transport routes, episodic events as introduction mechanisms, migration routes and impact of

climate change on species distributions is featured. Patchiness in the vertical as well as in the horizontal due to mesoscale and small-scale structure is a defined research topic.

Protected species dynamics focuses upon the refinement of acoustic sensing and tagging methods, the study of population dynamics, habitat utilization, foraging habitats, and diving physiology of marine mammals. In addition, the impact of anthropogenic sound on the migration routes and behavior of these mammals is a study area necessitated by the Marine Mammal Protection Act and the increase of anthropogenic activity such as shipping, drilling and general development of the near shore zone.

Protected areas and reef systems ecology seeks to do research aimed at protecting marine habitats from anthropogenic change. Reef habitats in particular may harbor clues to past changes in climate in their physical structure. These sensitive systems harbor a diverse community and can represent a historical record of past climate events. In many cases, these habitats are threatened and in need of mitigation.

C.   Research in Extreme Environments

A third theme area for the JIMO is centered on research in extreme environments. In all of the following cases, research necessarily includes the development of rugged sensors, platforms and data transmission devices to perform under adverse conditions. The "adverse conditions" range from ice to high pressure, high temperatures, fog, hurricanes, sulfur pools and anoxia to name a few. The theme area is divided into four major thrusts:

Sea-floor processes emphasize the characterization of unexplored environments and subsequent process definition in these newly described habitats. Hydrothermal vent processes continue to be an area of interest for biologists, chemists and geologists. The physiology and physiological ecology of these organisms such as extremophiles and sulfur bacteria are of interest. Vent chemistry and heat transfers into abyssal waters are areas of potential study. Ridge processes and associated crustal dynamics constitute a significant fraction of the proposed research. Methods for the better characterization of these processes or for shelf topography of the seafloor are included.

High-latitude research defines the functional dynamics between Antarctic krill populations, their environment and their predators use bioacoustic and conventional technologies to acquire data for input into pelagic ecosystem models. UV radiation and ozone abundance monitoring and modeling and prediction of health effects will be a major research topic in this thrust area. Cycles and controls of ocean production in high latitudes extending into the southern ocean and characterization of seasonal circulation patterns in the Arctic and Antarctic are included in this topic area.

Strongly forced systems studies focuses on monsoonal dynamics and variability, hurricane prediction and observations including tracking and modeling, and research in hazard impacted areas.

Toxic environment research takes place at the limits of biological survival. Anoxic waters, sulfur pools, and heavy metal contaminated sediments present difficult regions for measurement. Most of the extreme conditions are due to chemical or geochemical processes causing noxious conditions.

D.   R&D on Observation Systems

The fourth theme area for research is unique in its cross cutting nature. Observation system development ensures that there is state-of-the-art research and development efforts brought to bear on scientific problems. Platforms and instrumentation re-engineering, observing system reconfiguration, and data merging and display techniques modification take place here. This is the engineering component of a smoothly operating research effort.
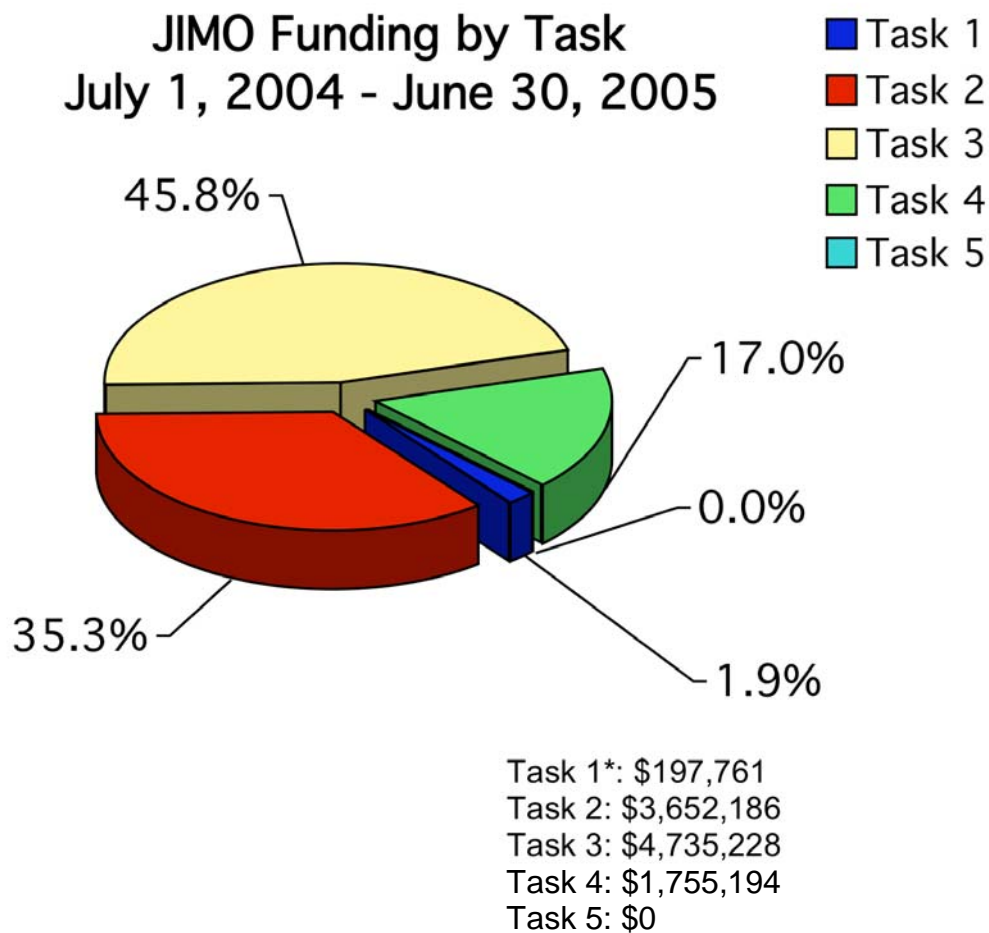
Extreme technology development focuses on rough weather deployable mooring, low threshold detection optical/chemical sensors, high pressure/heat tolerant probes, optic/acoustic nets/pens for stock assessment, queryable (pull) and push communications, minimal/self tending arrays, non-fouling chemical sensors, and aircraft deployable sensors/drifters/buoys. Improved ROVs and submersibles are among the technologies that need to be developed, refined or redesigned. Acquiring enabling technologies and platforms such as the potential addition of new SIO submersibles will significantly expand the research capabilities of the JIMO.

Systems engineering evaluation allows a probing look at the optimal design at the observation system as a system rather than a sum of the components. The goal is to evaluate the existing observing systems and optimize the system at all levels including sensor, instrumentation, platform and sampling design and to reassess the systems architecture at various intervals. Such an ongoing in-depth look at observing systems will ensure the evolution of the systems as the state of the art of science develops.

Information systems management is conducted in close collaboration with the NOAA units that have direct responsibility for this function and is consistent with US Ocean Data Management and Communications standards. Excellent examples, involving NWS' NDBC, build upon previously funded NSF programs including ROADNet (Real-time Observatory, Applications, and Data management Network). HPWREN (High Performance Wireless Research and Education Network), OptIPuter (Optical IP computer) and LOOKING (Laboratory for Ocean Observatory Knowledge and Information Grid) as well as major California programs especially COCMP. Quality assurance and control of data as well as the dissemination of that data to scientific users in near-real-time is a critical function.
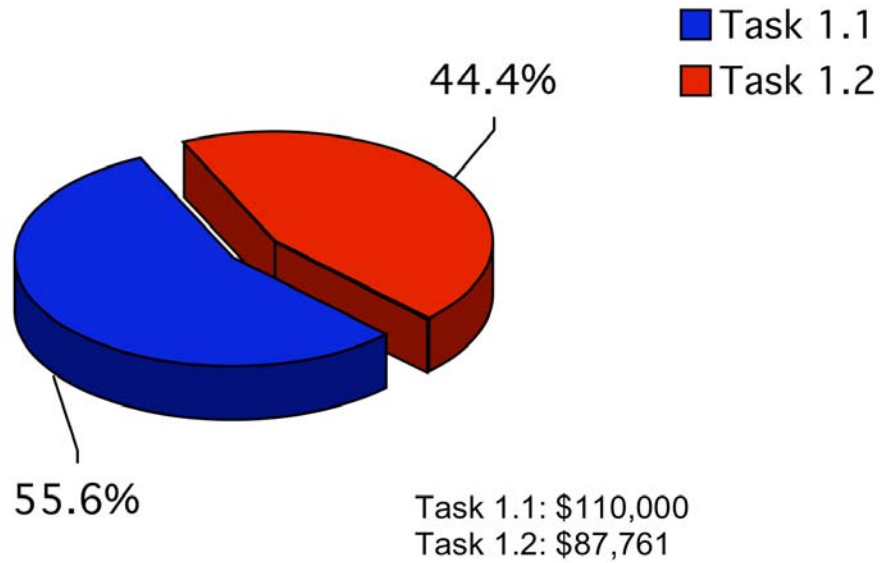
Systems modeling and simulation is an essential part of the information transfer of the research. Here the data are presented to give the most information to the potential user. The scientific models may be coupled with socio-economic or development models for use in policy making. The appropriate simulation, visualization, and web-based techniques important for operations and research also help in the dissemination of the data for educational purposes to the public or K-12 level.
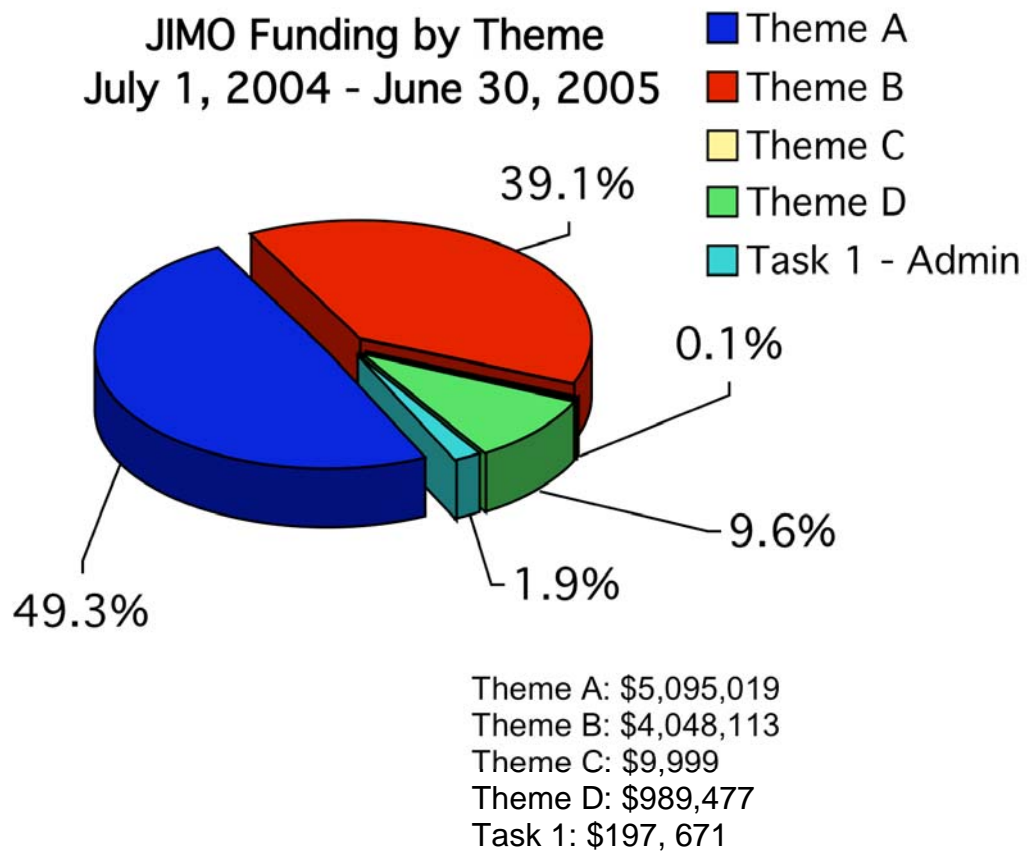
JIMO Funding by Task
July 1, 2004 - June 30, 2005

- Task 1
- Task 2
- Task 3
- Task 4
- Task 5

45.8%

17.0%

0.0%

35.3%

1.9%

Task 1*: $197,761
Task 2: $3,652,186
Task 3: $4,735,228
Task 4: $1,755,194
Task 5: $0

* See **JIMO Task 1 Funding** graph for break down of 1.1 and 1.2 funding

JIMO Task 1 Funding
July 1, 2004 - June 30, 2005

■ Task 1.1
■ Task 1.2

44.4%

55.6%

Task 1.1: $110,000
Task 1.2: $87,761

JIMO Funding by Theme
July 1, 2004 - June 30, 2005
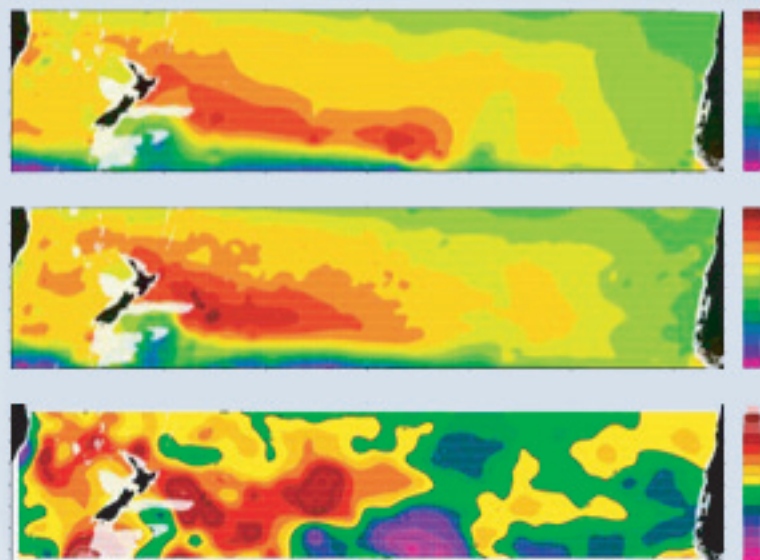
■ Theme A
■ Theme B
□ Theme C
■ Theme D
■ Task 1 - Admin

39.1%

0.1%

49.3%

9.6%

1.9%

Theme A: $5,095,019
Theme B: $4,048,113
Theme C: $9,999
Theme D: $989,477
Task 1: $197, 671

Consortium on the Ocean's Role in Climate (CORC)

Russ Davis (SIO)

NOAA Technical Contact: Mike Johnson (OGP)
Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance
Society's Ability to Plan and Respond

Research Objectives and Specific Plans to Achieve Them

The broad objectives of the Consortium on the Ocean's Role in Climate (CORC) are (1) to maintain critical elements of an ocean climate observing system in the Pacific Ocean, and (2) to develop new observational and data assimilation methods for documenting and diagnosing climate change in the ocean.

CORC progress in this period met expectations. Basin-scale surface-temperature and surface-current measurements by drifter, VOS surface meteorological observations, and high-resolution XBT/XCTD sections were carried out at the pace proposed. Development of a data-assimilating model of the tropical Pacific is advancing, as are technical improvements of the 'Spray' underwater glider and the Underway CTD

Approach, Evaluation and Methodology

Scientists from Woods Hole Oceanographic Institution (WHOI) and Scripps Institution of Oceanography (SIO) collaborate in the CORC projects:

- D. Roemmich, B. Cornuelle and J. Sprintall (SIO) collected observations of climate-related variation in the ocean's transport of heat and water using high resolution XBT/XCTD (HRX) transects, in conjunction with Argo and satellite altimetry, to diagnose the storage of those variables.

- P. Niiler (SIO) coordinated observations of surface temperature for referencing satellite SST retrievals and climate related changes in near future circulation to diagnose the causes and dynamics of these changes using Surface Drifters.

- R. Weller (WHOI) conducted surface meteorology from volunteer observing ships.

- D. Cayan (SIO) conducted analyses of surface flx forcing of climate variability

- B. Cornuelle and A. Miller (SIO) developed data-assimilating modeling system for the Tropical Pacific

- R. Davis (SIO) used Underwater Gliders for Monitoring Ocean Climate.

- D. Rudnick (SIO) development and implemented the Underway CTD to collect inexpensive profiles of salinity from volunteer observing ships (VOS).

Research Accomplishments

- Quarterly High Resolution XBT/XCTD hydrographic sampling from VOS, including high resolution sampling in boundary currents, was continued along six basin-spanning lines in the Pacific and Indian Oceans. Archived data was incorporated in regional and global analyses:
- Willis et al (2004) estimated global ocean heat content and thermosteric sea level rise for the period 1993 to 2003 using a combination of XBT and satellite altimetry.
- Sutton et al (2005) used XBT data to determine the vertical structure and magnitude of the decadal warming signal in the Tasman Sea, one of the regions with the strongest warming in the past decade.
- A closed heat budget, on interannual time-scales for a large ocean area in the southwestern Pacific was described by Roemmich et al (2005). The interannual variability in air-sea flux, ocean heat flux convergence and air-sea flux in the upper 100 m was balanced to within 6 W/m**2. This is the first study closing the interannual heat balance using subsurface measurements of ocean heat flux convergence.
- As part of the Surface Velocity Program, 74 CORC drifters were deployed in the tropical Pacific. Enhanced observations in the Strait of Luzon include 40 CORC and 60 ONR drifters to study exchange between the western Pacific and South China Sea.
- Twenty Sea Bird MicroCATs were installed on drifters to provide broad-scale coverage of surface salinity. Twelve were deployed in the Bay of Biscay and eight are planned for deployment in the South China Sea to study the Yangtze River outflow.
- One hundred CORC drifters deployed in the North Pacific Equatorial Countercurrent were used, along with altimetry, to analyze the dynamics of that current. Zonal currents were found to be geostrophic but meridional currents are semi-geostrophic with acceleration of the zonal flow playing an important role. This effect has heretofore been disregarded in studies of variability in the region.
- The CORC-developed Underway Conductivity Temperature and Depth (UCTD) is operational. It allows easy and safe operation on underway vessels, making no demands on vessel operators other than space on an aft quarter to put the equipment.
- A cruise in 2004, as part of the ONR-sponsored North Pacific Acoustics Laboratory (NPAL), included the first UCTD deployments by a group of users not involved in UCTD development. The results were encouraging. Over 170 casts were completed with only one lost probe. At this loss rate, UCTD cost per cast will be comparable to that of XBTs. Operations continued successfully on the third NPAL cruise.
- A second cruise in January 2005 was a test of UCTD on the NOAA *R/V David Starr Jordan*. The cruise allowed Valerie Andreassi and her group to evaluate UCTD for possible use by SW Fisheries. Andreassi extensively documented UCTD operation through photos and videos, and briefed others at SWFSC on the system.
- Analysis of 15 years of autonomous float data, including CORC SOLO floats, produced basin-wide maps of absolute mean velocity at intermediate depths in the South Pacific and Indian Oceans.
- Two CORC Spray gliders were used along with 3 ONR Sprays to map circulation and upwelling off Monterey Bay. Analysis shows scales of variability of O(2 days) and O(15 km) once the time varying alongshore flow is accounted for – this implies that detailed mapping near coasts may be very difficult even with data assimilating models.
- In collaboration with William Kessler (PMEL), we have begun repeated crossings of the Pacific's South Equatorial Current from New Caledonia to the Solomon Islands to monitor variation of the South Equatorial Current that feeds the Equatorial Undercurrent.
- The monthly Surface Flux Analysis of the Pacific Ocean using bulk formulae for heat flux and wind stress was extended to 2004 using the last two years of COADS marine data. Diagnosis of the differences in flux estimates derived from daytime vs. nighttime marine observations continued.
- Automatic Improved METeorology (AutoIMET) sensor packages were maintained on two Voluntary Observing Ships to provide frequent high quality marine surface observations for surface flux determination in the Pacific. In March 2005 one ship was moved to the Atlantic and a replacement has not been found. The AutoIMET packages are working well with minimum maintenance.
- The CORC data assimilation model for the tropical Pacific is now using, in addition to altimetry, satellite SST and climatological T and S, most tropical Pacific data sets including TAO, drifters, CTDs, XBTs, CORC and Argo profiling floats, QuikSCAT winds and Greg Johnson's analysis of mean currents. Error covariances for all these new data were developed and tested.
- The procedures for assimilating individual profiles into the MIT-GCM model and adjoint were improved to make possible many-year runs with frequent assimilation. Progress has also been made in developing a model of low trophic levels (nutrients and phytoplankton) that will be ported to the MIT-GCM upon which the CORC system is based.
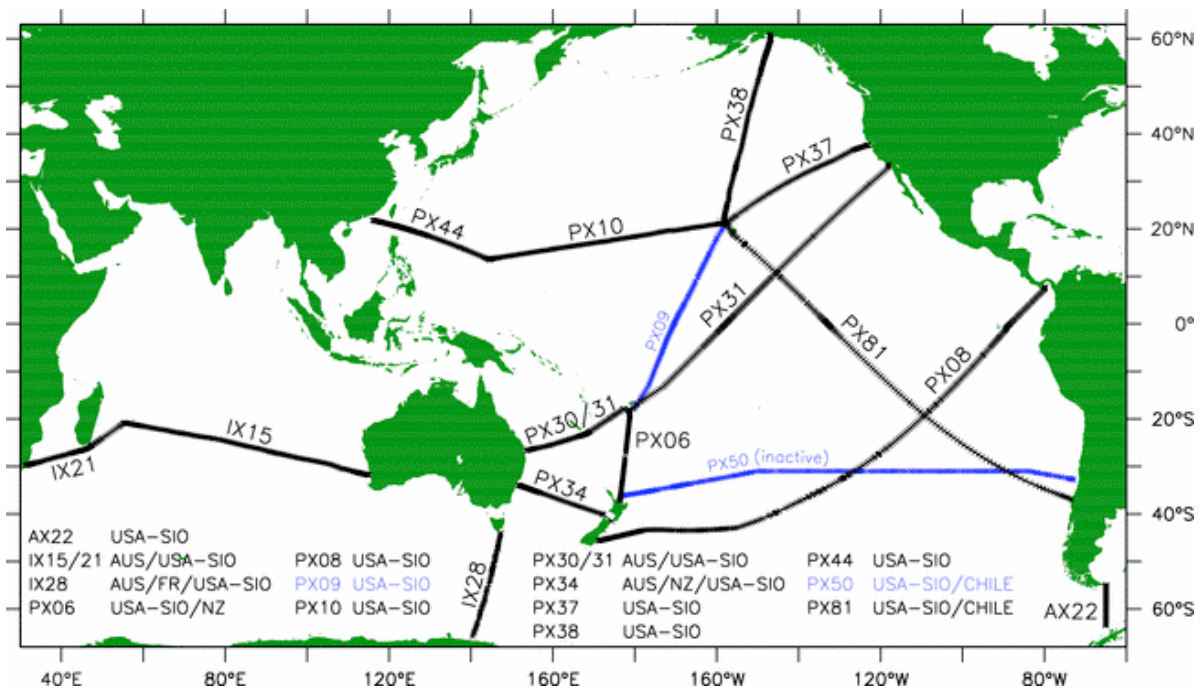
Fig.1 The network of high-resolution XBT/XCTD hydrographic sections supported by CORC. Each section is occupied quarterly.
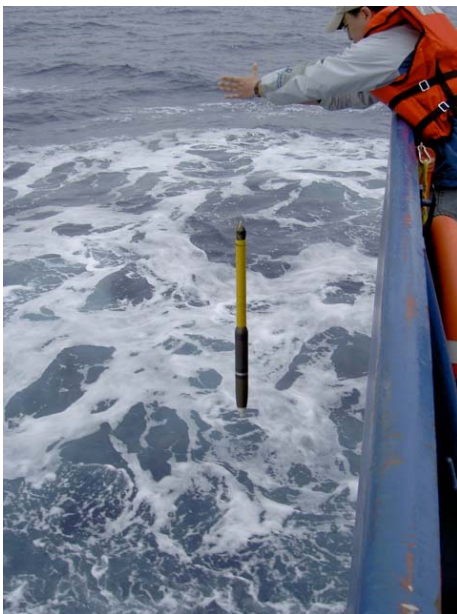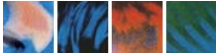

Fig. 2 The CORC-developed Underway CTD being deployed. The probe permits low cost sampling of Conductivity, Temperature and Depth in the upper ocean from underway vessels including high-speed VOS.

## Consortium on the Ocean's Role in Climate (CORC) - Abrupt Climate Change Studies (ARCHES)

Peter Niiler (SIO) and Various Investigators (LDEO, WHOI, Univ. of Maine, CEFAS)

NOAA Technical Contact: Kenneth Mooney (OGP)
Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Until the current reporting year, the CORC-ARCHES program was funded as part of JIMO because of its relation to CORC (PI: R. Davis). In 2004, the Cooperative Institute for Climate Applications and Research (CICAR) was established at the Lamont-Doherty Earth Observatory (LDEO) at Columbia University. Because the majority of ARCHES investigators have a primary affiliation with LDEO, the ARCHES program transferred over to CICAR from JIMO. However, due to financial extensions, JIMO is co-reporting on ARCHES with CICAR for this period. For the full CORC-ARCHES report for the current reporting period, please refer to CICAR's annual report, which can be found at http://www.ldeo.columbia.edu/cicar/
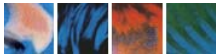
Global Drifter Program (GDP)

Peter Niiler (SIO)

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Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Research Objectives and Specific Plans to Achieve Them

The "Global Drifter Program" (GDP) is the principal international component of the JCOMM "Global Surface Drifting Buoy Array". It is a Scientific Project of the DBCP of WMO/IOC. It is a near-operational ocean-observing network of drifters that, through the ARGOS satellite system, returns data on ocean near-surface currents, SST and atmospheric pressure (and winds, subsurface T(z) and SSS) and provides a data processing system for scientific utilization of these data.

The scientific objectives of the GDP, and its operational and research partners, are to:

• Provide to GTS an operational, near-real time data stream of SST, sea level pressure and surface velocity.
• Observe the mixed layer velocity on a global basis with 0.5° resolution and, jointly with satellite altimeter data, produce new charts on the seasonal and interannual changing circulation of the world ocean at 0.5º resolution.
• Develop and introduce into the drifter construction technological advances in sensors, electronics, power, methods of assembly and deployment packaging.
• Provide enhanced research quality data sets of ocean circulation that include drifter data from individual research programs, historical data from instruments different from the SVP Lagrangian Drifter and the corrected data sets for wind-produced slip of drifter velocity (Figure 1).

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Approach, Evaluation and Methodology

Since October 2003 the global drifter array has consisted of over 900 drifters. Full implementation of the 'required 1250-element array for SST observations will be completed by September 2005. This 'required' global drifter array size by JCOMM is based on the need to return instrumental observations of daily average SST (+/-0.10C) over the global ocean at a 5⁰ resolution, or the spatial scale of the error covariance function of operational NOAA satellite infrared SST sensors. Surface pressure sensors are also supported by national meteorological agencies based on regional needs. The actual number of drifters in the array will be larger than 1250 because the required uniform spatial distribution will be difficult to maintain in the complex ocean surface circulation and many drifters go ashore in remote locations and continue to transmit. In 2005-2006 period will begin more directed efforts to adjust the array spatial density with more uniform coverage than the present 60% of the surface of the ice-free ocean.

Even though no internationally mandated operational requirement for surface velocity exists, nearly all research program contributions to the drifter array have been justified on the basis of upper ocean velocity observations. In the research community 99% of reviewed scientific research papers make principal use of drifter velocity observations: (viz. list of peer-reviewed research publications at: http://www.aoml.noaa.gov/phod/dac/drifter_bibliography.html). We anticipate that in the very near future, a surface velocity observation requirement will also be instituted.

Research Accomplishments

Full implementation of the "Global Surface Drifting Buoy Array"

In 2004, 905 drifters with SST sensors were built and delivered by JIMO to AOML for deployment before June 2005. With the approval of UCSD Chancellor for advance spending of FY'05 funds, an additional 220 SVP drifters were built and delivered to AOML for deployment by July 30, 2005. In FY'05 JIMO will have purchased 940 drifters and AOML purchased 60 drifters, for total NOAA contribution of 1000 drifters to the JCOMM "Global Surface Drifting Buoy Array". This marks a second consecutive year of increase over FY'03 (666 JIMO drifters) and with, full cooperation of JIMO national and international partners, the "Global Surface Drifting Buoy Array" will by September 2005 the first global ocean observing system for climate studies to be fully implemented.

Design and construction of thermistor chains for hurricane studies

The thermistor chain development was in response the requirements of the National Hurricane Center to improve hurricane strength prediction using subsurface temperature information. To this end, we have developed, with Clearwater, Inc., the methodology for attaching digital-inductive modems on to subsurface, coated wire drifter tethers.

Minimet wind drifter deployment

The first successful deployment of a Minimet wind drifter occurred in the ONR/NLIWE in South China Sea, where complete data was retrieved from 200m-long thermistor chains with 20 temperature and 5 pressure sensors. In 2005, we have assembled 8 similar chains on to Minimet drifters for air-deployment in front of two North Atlantic hurricanes.
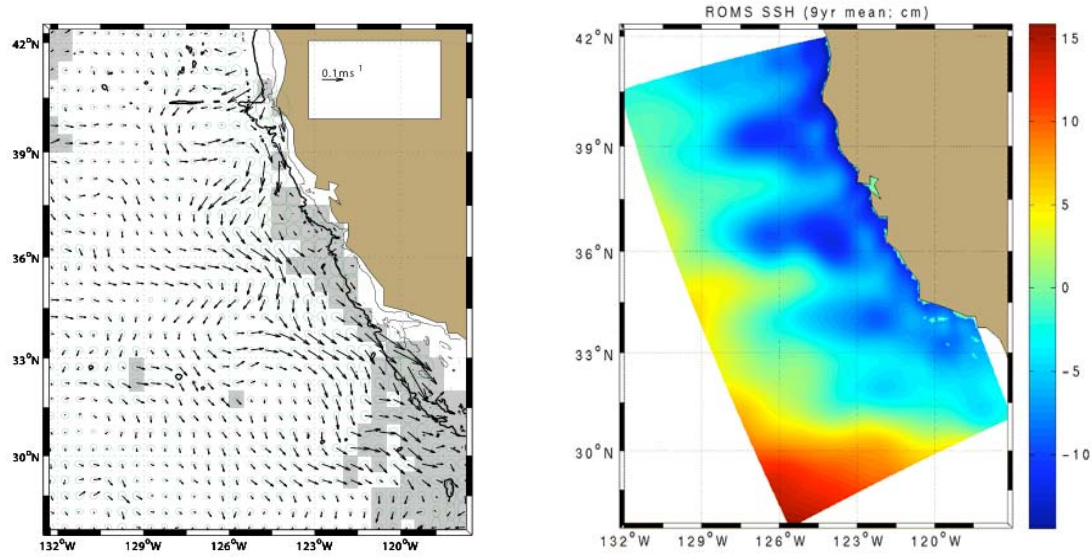
Fig. 1 The ensemble mean geostrophic drifter velocity of the California Current (left panel) and 9-year time mean sea level from ROMS model (right panel, courtesy of J. C. McWilliams, 2004). In both the drifter data and the model appear heretofore unknown four semi-permanent meanders.
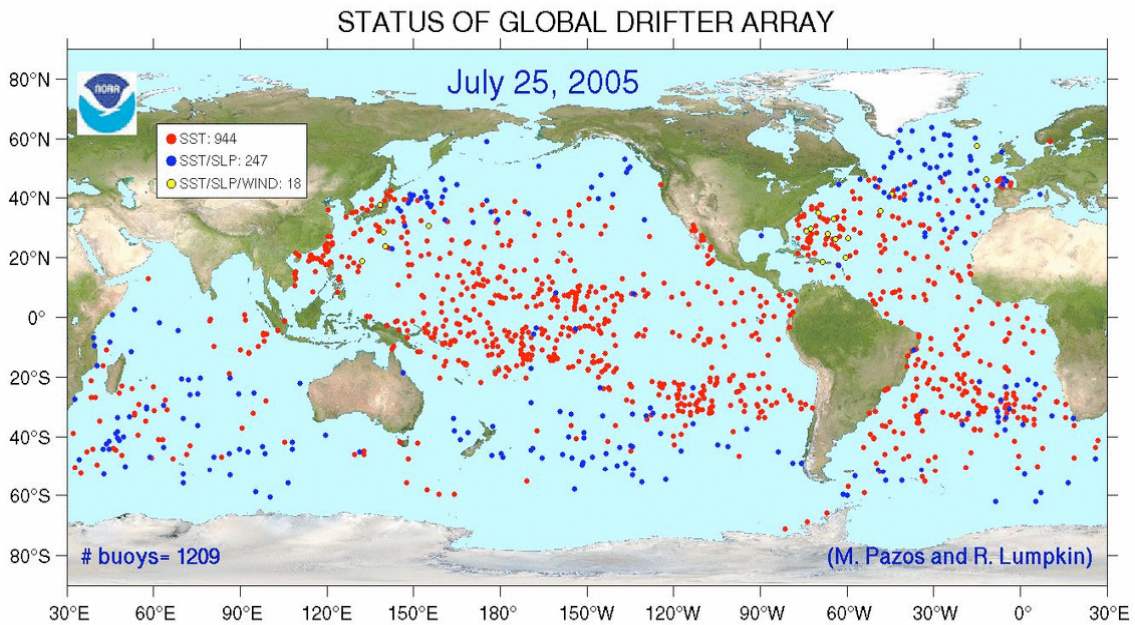

Fig. 2 The Global Drifting Buoy Array on July 25, 2005. The required array of 1250 drifters will be completed by September 2005.
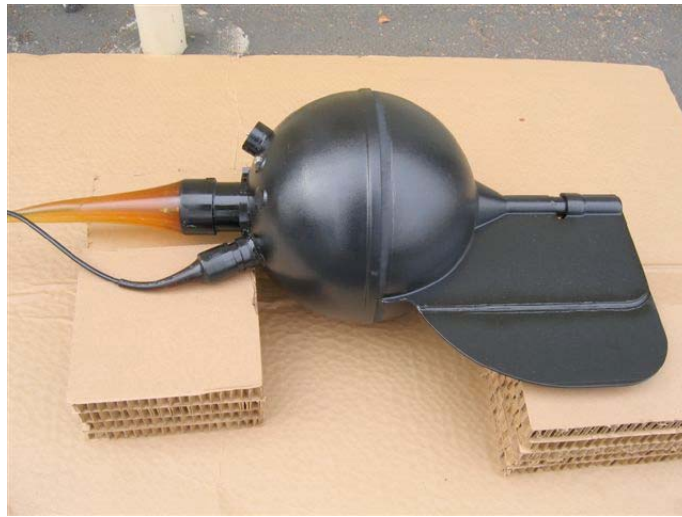
Fig. 3 Photograph of the surface float of a Minimet wind drifter that is attached to a thermistor chain. The wind speed is determined from ambient noise with a hydrophone whose cable is protruding at an angle from the bottom of the float.

The Argo Project: Global Ocean Observations for Understanding and Prediction of Climate Variability

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Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
NOAA Goal 3: Serve Society's Needs for Weather and Water Information

Research Objectives and Specific Plans to Achieve Them

Argo is an international collaboration providing a global array of profiling CTD floats for a broad range of operational and scientific applications (http://www.argo.ucsd.edu). The Argo array, now including over 1900 active floats, is providing unprecedented real-time views of the evolving physical state of the ocean. Argo measurements reveal the physical processes that balance the large-scale mass, heat, and freshwater budgets of the ocean on basin-to-global scale. Argo is a large initiative for oceanography, merging research and operational objectives to provide a uniquely valuable global dataset for climate science, ocean state estimation, seasonal-to-decadal forecasting, and other applications. All Argo data are freely available in near-real time.

Approach, Evaluation and Methodology

SIO is one of 5 institutions responsible for the full implementation of the U.S. component of the international Argo project. U.S. Argo produces and deploys about 400 floats per year, collaborating with the international program to ensure global coverage. U.S. Argo also maintains a data assembly center for delivery of real-time and research quality (delayed-mode) data from U.S. floats.

The specific roles of SIO Argo include:
- Production and deployment of 105 floats per year.
- Technical development and improvement of profiling floats for Argo (R. Davis)
- Participation in the Argo data system through delayed-mode scientific quality control

- Leadership of the international Argo by J. Gould (Argo Director) and D. Roemmich (Chairman, Argo Science Team), and coordination of the U.S. Argo Consortium (SIO, WHOI, UW, NOAA/PMEL, NOAA/AOML)

Research Accomplishments

- During the past year (07/2004 – 06/2005), 144 SIO Argo floats were built, shipped to remote destinations, and deployed. All but 2 of these instruments are presently active. This brings the total number of active SIO Argo floats to 275 out of an international total of 1922 Argo floats. Argo is now a global array, and is approaching completion. (Fig. 1) For all active floats, profile and engineering data are carefully monitored to identify any technical problems with the instrument or sensor.
- A collaboration between SIO, UW and Argo New Zealand resulted in three Argo deployment cruises using New Zealand research vessels in the subtropical South Pacific, the tropical Pacific and the Southern Ocean. These deployments filled an enormous gap in Argo coverage, essentially making the array a global one.
- The Scripps Instrument Development Group, under R. Davis, made substantial improvements in design and production of SOLO/Argo floats leading to greater instrument reliability and lifetime. Technology development has concentrated in two areas: Previous problems with vacuum leaks in the float's air pumping system have been greatly reduced, and a redesign of the high pressure pumping system to enable greater buoyancy adjustment is underway, with prototype instruments to be produced in the near future.
- J. Gilson developed a graphical user interface (GUI) which allows Argo salinity experts to carry out scientific quality control of Argo data. The Gilson GUI has been adopted by international Argo partners. All eligible SIO Argo float profiles have completed the scientific quality control process and are available via the global data centers.
- D Roemmich et al (2005b, Submitted) illustrated the ability of the Argo array to resolve temporal variability on large spatial scales in the geostrophic circulation of the oceans. It was shown that the deep subtropical South Pacific gyre increased its counterclockwise circulation on decadal timescale in response to wind-forcing. (Fig. 2)
- J Gould continues as Argo Director. He manages the Argo Project Office and supports a variety of AST activities. A major focus this year has been identification of operational users of Argo data and communication with the operational groups.
- D Roemmich has been Chairman of the international Argo Steering Team since its inception in 1998. An AST-Executive meeting was held in Australia in February 2005, with a full AST meeting planned in India in January 2006. Roemmich represents Argo science at numerous conferences and meetings.
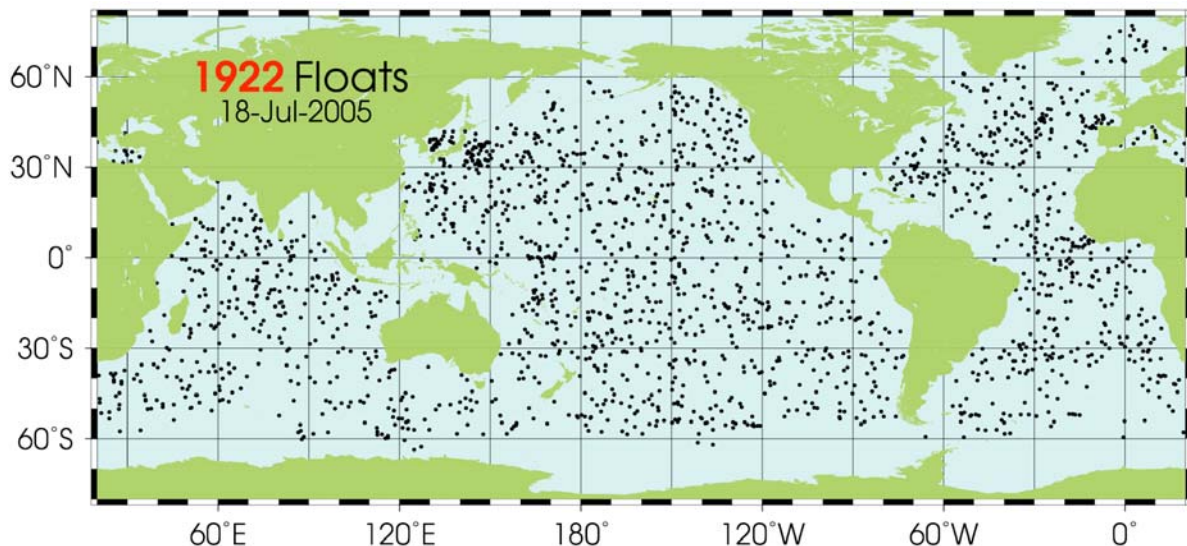

Fig. 1 There are now over 1900 active Argo floats in the global array, which is nearly two-thirds of the completed array. During the coming year, the remaining gaps will be filled and the density of coverage will be increased.
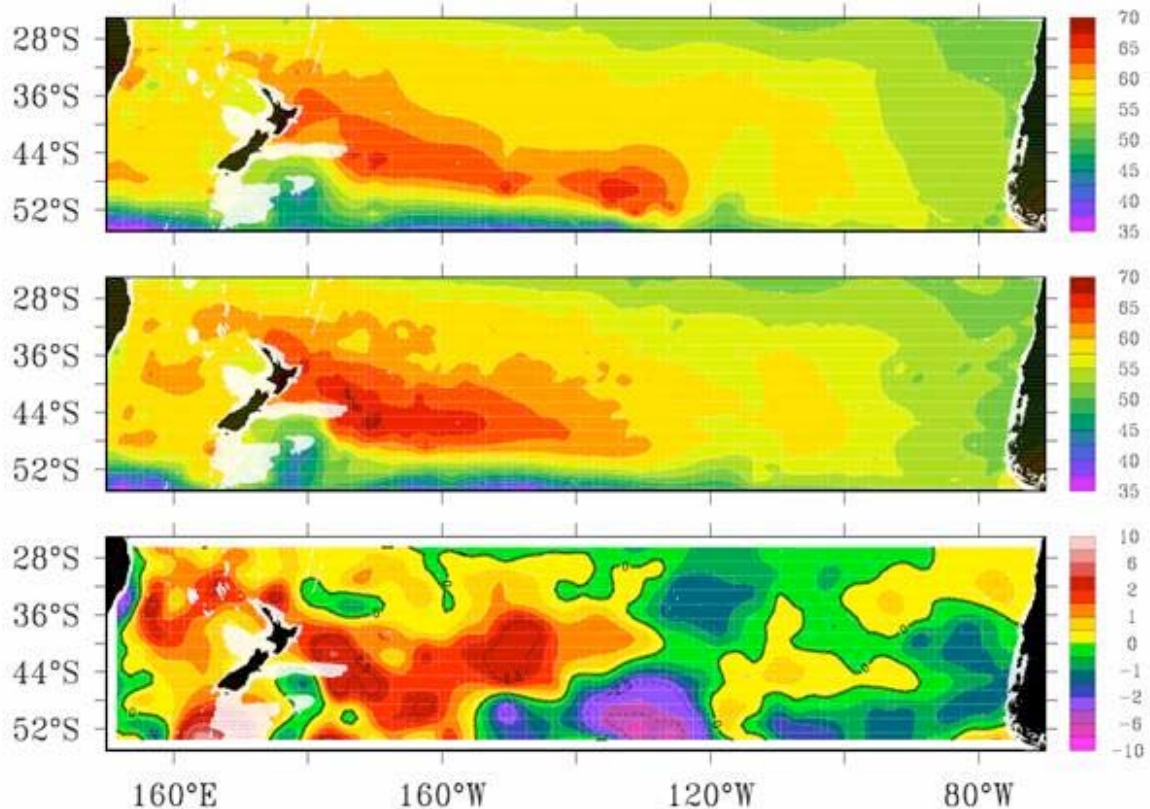
Fig. 2 Dynamic height (dyn cm, 1000/1800 dbar) from the WOCE survey (1991-1996, top panel), Argo (2003-2005, middle panel), and the WOCE-minus-Argo difference (bottom panel) shows an acceleration of the subtropical gyre, by about 30% at 1000 m. The signal extends from the sea surface to more than 1800 m depth (from Roemmich et al, 2005 submitted)

Scripps Experimental Climate Prediction Center (ECPC)

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Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Research Objectives and Specific Plans to Achieve Them

The goal of the ECPC is to develop an integrated global to regional climate prediction system by:

• Identifying coupled modes of interannual variability
• Developing models capable of predicting these modes
• Evaluating the predictive capability of these models
• Transferring methodologies to NCEP, IRI, and Regional Application Centers

Approach, Evaluation and Methodology

Persistent surface anomalies in the ocean and land have a strong influence upon atmospheric features that would otherwise be unpredictable beyond a few weeks. We use these persistent anomalies to force experimental state of the art dynamical models initially acquired from national centers (e.g. NCEP) and then further develop these models within the ECPC. We then perform forecast experiments to evaluate the predictive capability of these models. As part of this examination, experimental predictions are made routinely in order to assess the accuracy and usefulness of these forecasts. These experimental predictions are available to the general public graphically via our WWW site and in digital form to interested outside researchers. We subsequently attempt to transfer these models to NCEP, IRI, and Regional Application Centers.

Research Accomplishments

ECPC currently uses the reanalysis I version of the National Centers for Environmental Prediction's (NCEP's) medium range forecast (MRF) model or global spectral model (GSM) to make routine experimental global and regional forecasts daily (out to 14 days) and weekly (out to 16-weeks) starting from the NCEP operational 00UTC global analysis with persisted SST anomalies (+climatology) as a lower boundary condition. The GSM forces a consistent regional spectral model (RSM) in order to gain increased spatial resolution (50-25 km resolution) for several selected regions (US, CA). The GSM forces a Pacific Basin Ocean Model in order to develop seasonal ocean forecast applications. The GSM forces a single column model (SCM), which was previously used to diagnose cloud and radiation profiles over the ARM sites, is now being used to predict detailed characteristics of the atmospheric vertical structure up to a week in advance. Current output products from the GSM/RSM, which are displayed on the world-wide web (http://ecpc.ucsd.edu) include a fire weather index and associated variables such as 2m-temperature, relative humidity and 10m-windspeed as well as precipitation and soil moisture. Additional variables from the RSM are being used to drive fire danger code describing the USFS National Fire Danger Rating System. The fire danger code depends upon past history and must be integrated continuously, using precipitation observations as well as RSM forcings. An innovative feature is that we now download precipitation observations in near real time to force a firedanger model and this new capability may pave the way for future Land Data Assimilation System efforts within the ECPC. These experimental fire danger forecasts (e.g. Roads et al. 2005) are also being displayed at various external sites, including the NCEP Climate Prediction Center, as an experimental aid in long range planning.

The ECPC GSM/RSM weekly 4 month forecasts have recently been augmented by an ensemble (10) monthly 7 month forecast using an updated version of NCEP's seasonal forecast model (SFM), which is based on updated physics from the NCEP/DOE reanalysis II (Kanamitsu et al. 2002). The new SFM has a nominal (a reduced grid technique is used near the poles) horizontal resolution of T62 (about 2o). There are 28 levels in the vertical sigma coordinate system. ECPC's SFM is run in a different fashion from the GSM forecasts. The SST forcing for these 7 month forecasts come from a simplified model for the tropical Pacific and are produced by the IRI. The 10-member 7-month forecast is now routinely made and submitted to the IRI. The ECPC-SFM forecast has been accepted as one of the standard members of the IRI multi-model ensemble forecast (NCEP, NCAR, NASA, GFDL, ECPC). Our hindcast scores have been found to be comparable to other major models, thus adding a new valuable source of information for the IRI. Forecast products are also sent to NCEP and are regularly used in their operational seasonal forecasts.

A new RSM has now been developed from this new SFM and much effort was put into making the SFM and RSM as similar as possible. It is now possible to run both the SFM and RSM with similar physics and we now refer to the new ECPC global to regional modeling system as the ECPC G-RSM. Although the heritage of our modeling system comes from NCEP, there are now distinct differences. For example, the previous OSU land surface scheme has now been replaced by the modular Noah land surface scheme. Fig. 1 shows a recent 25-year simulation with the RSM in comparison to the North American Regional Reanalysis. The parameterized (relative humidity) cloud scheme is being replaced by the NCEP prognostic cloud scheme, which will be key to eventually incorporating other cloud and radiation schemes.

We are now combining our currently separate GSM/RSM and SFM forecasts into a unified and seamless suite of daily to seasonal G-RSM forecasts. Accordingly, we have begun to repeat the previous weekly 4-month forecasts (Sept. 27, 1997-present) for the globe and US (RSM) with the new G-RSM and are working toward making these G-RSM forecasts daily as an augmentation to the current single weekly forecasts and as an augmentation to the current monthly forecast ensembles. We believe this ensemble of daily forecasts will

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provide additional value at both long and short range, although we still need to examine the time period for which the ensemble average becomes more skillful than the most recent forecast.

The new SFM is also being coupled to the MIT and ROMS ocean models (see e.g. Fig. 2) and sometime in the future we hope to demonstrate that such a coupled system is better than current persisted or forecast SSTs as well as our current OPYC ocean forecasts. This coupled system will be used primarily for experimental seasonal climate prediction, but also has the potential to be used for a wide range of applications, including global warming studies. Also, an independent and more accurate dynamically coupled forecast should complement NCEP's and IRI's coupled prediction efforts and may eventually result in an improved coupled ocean-atmosphere forecast ensemble.
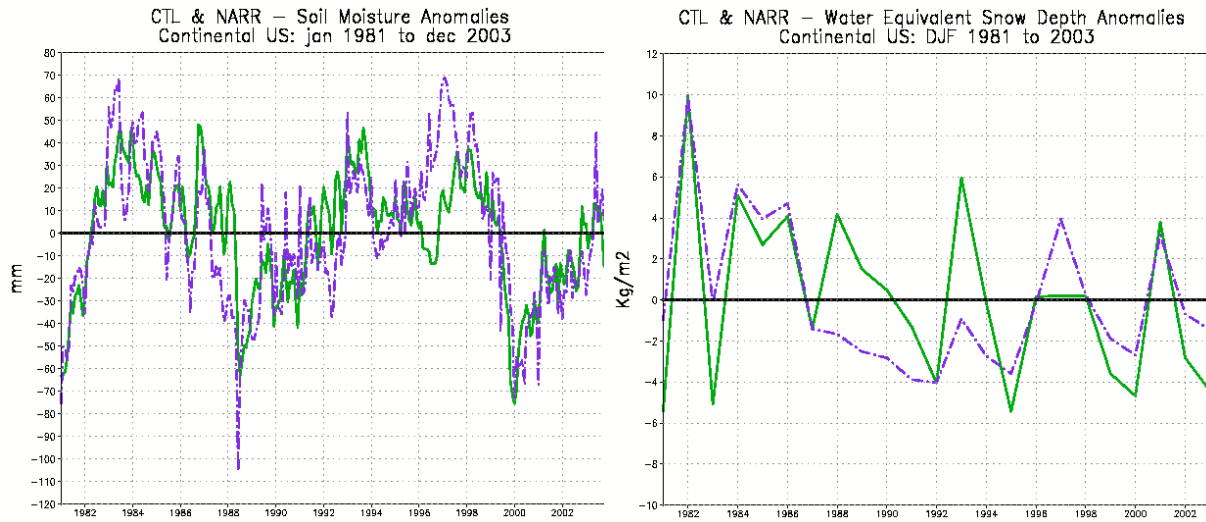

Fig. 1 Monthly mean variation of the anomalies of soil moisture (SM, in mm, top) and water equivalent snow depth (WEASD, in Kg/m2, only DJF averages, bottom) for CTL (green) and NARR (violet) over the continental US (130°-64°W; 30°-48°N), considering only land points. The mean standard deviations are: 26.1 (31.2) mm for CTL (NARR) SM, 4.2 (3.6) Kg/m2 for CTL (NARR) WEASD.
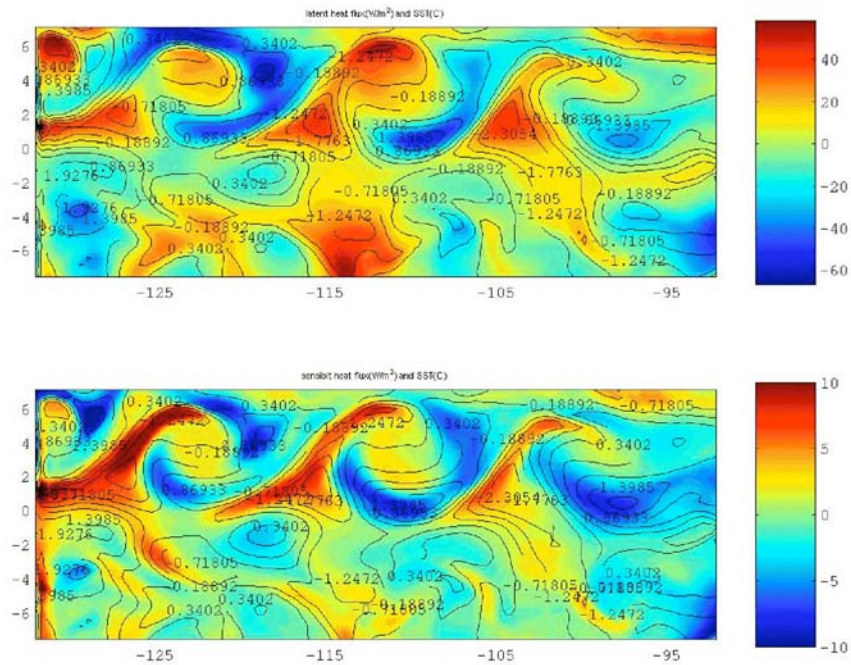
Fig. 2 (a) Latent heat flux and SST contour (°C), (b) sensible heat flux and SST contour. The convention here is that positive fluxes warm the ocean, negative fluxes cool the ocean.

Improved Cloud-Radiation and Hydrologic Cycle Parameterizations for Modeling and Predicting Climate Variability

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Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Research Objectives and Specific Plans to Achieve Them

A major focus proposed for this project was the development of improved parameterizations of cloud-radiation effects and related processes, using the diagnostic SCM to make direct comparisons of results from parameterizations with satellite remote sensing observations. These parameterizations were to be based on physically comprehensive detailed cloud microphysics modules derived from earlier and ongoing work by our group at Scripps and our collaborators.

Our principal goal in Year 1 was to have parameterizations evolved to the stage where they are ready for incorporation and testing in the GFS and other models under development at NCEP.

Approach, Evaluation and Methodology

In collaboration with Dr. Masao Kanamitsu and a visitor to his group at Scripps, Dr. Akihiko Shimpo, we have made major progress toward incorporating our improved parameterizations into the version of the EMC GFS model running at Scripps under the direction of Dr. Kanamitsu.

EMC has undertaken to provide code and expertise needed for putting the EMC GFS physics package into the Scripps SCM, together with the new cloud-radiation schemes, and to aid in comparing results between ARM observations and the various NCEP/Scripps parameterization combinations.

Research Accomplishments

Major progress has been achieved in improving the cloud microphysics parameterizations via testing and development. Our single-column model is used to evaluate the performance of two types of autoconversion parameterizations. The model results have been compared to data collected at the DOE Atmospheric Radiation Measurement Program's Southern U.S. Great Plains site. The model is run over a period covering two years (2000-2001) and the results are analyzed for time periods varying from hourly to seasonal. During a relatively short 27-hour period during March 2000 characterized primarily by shallow frontal clouds, modeled values of cloud liquid water were better simulated using a Manton-Cotton type autoconversion parameterization. However, over longer timescales representing a multitude of different cloud types and meteorological conditions, a Sundqvist type parameterization produced better results. Analysis of the model results indicates that the Manton-Cotton type parameterization does better during periods when shallow clouds are present without any overlying clouds, while the Sundqvist type parameterization is preferred during periods when high and low clouds coexist.

The dependence of the autoconversion rate on the cloud droplet concentration (Nc) is only implicitly included in the Sundqvist parameterization while the Manton-Cotton parameterization contains an explicit dependence on Nc. Limited in-situ measurements suggest that Nc varies significantly in time, however the single-column model as well as most general circulation models specify Nc as a constant value. Sensitivity tests using the Manton-Cotton parameterization indicate that the autoconversion rate is sensitive to the specification of Nc. Mean values of cloud liquid water content increased with increasing values of cloud droplet concentration. The mean modeled top of atmosphere cloud radiative forcing during the two-year period 2000-2001 differed by as much as 10 W m-2 as the cloud droplet concentration was varied between minimum and maximum values suggested by the in-situ measurements. These results imply that model produced hydrological cycle and cloud-radiation interactions could be better modeled using an accurate time dependent measure of the cloud droplet concentration.

US and Global Water and Energy Budget Studies: A Contribution to CEOP

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Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Research Objectives and Specific Plans to Achieve Them

As part of the Coordinated Enhanced Observing Period (CEOP), there are several global reference sites that provide a number of in situ observations of water and energy budget study (WEBS) variables for the period Jul. 1, 2001-Dec. 31, 2004. Processed satellite data (geophysical variables) will also eventually be available at these sites. NWP centers have been requested to archive a more complete synoptic gridded output set and there may eventually be corresponding gridded satellite data. Developing the hydroclimatological output from these data sets has required a special effort and the Experimental Climate Prediction Center is providing

extensive reanalysis output from the NCEP/DOE Reanalysis II (RII) and an upgraded version of RII using our new Seasonal Forecast Model (SFM). In addition, as part of the Inter-CSE Transferability Study (ICTS) we are providing corresponding regional simulations from our corresponding Regional Spectral Model (RSM). Our overall goal is to understand what components of the global water and energy cycles can be accurately measured, simulated, and predicted at regional and global scales. A particular goal is to isolate strengths and weaknesses of our global and regional models depiction of the diurnal cycle.

Approach, Evaluation and Methodology

We have made a special effort to provide all of the CEOP/WESP requested variables and processes for the entire CEOP period (7/1/2001-12/31/2004). This output includes top of atmosphere, integrated and vertically varying atmospheric and surface water and energy-cycle processes and variables. It should be noted that gridded output is developed first and archived locally, and then MOLTS (41 CEOP sites) are extracted from the gridded data. Depending upon outside requests, additional sites could be extracted later from the gridded output, which is also stored locally. As part of the pilot phase of CEOP, Roads et al. (2003) developed a preliminary comparison between the US National Centers for Environmental Prediction (NCEP) Seasonal Forecasting Model (SFM) being run at the Scripps Experimental Climate Prediction Center (ECPC) for CEOP, the US National Aeronautics and Space Administration (NASA) Data Assimilation Office (DAO) global model, and the NASA Global Land Data Assimilation System (GLDAS) land surface model with the Canadian Boreal Ecosystem Research and Monitoring Sites (BERMS) in situ observations (OBS).

Ruane et al. (2005) constructed a 3-month time series with a 3-hour interval from the 15-36 hour forecasts of each run. We then performed a least-squares fit to the diurnal and semidiurnal harmonics at each grid point, and average the amplitude and phase over a 3-year period. We have mapped the phase as color and the standard-deviation-normalized amplitude as intensity to represent the character of each diurnal cycle on a single plot. The Reanalysis II precipitation diurnal cycle displays many of the large-scale features observed, including a morning peak over the ocean and an afternoon peak over the continents. Observed regional characteristics are also well represented in summer analyses. These include a morning peak in precipitation over the southern Himalayas, a later peak over the mountainous portions of the United States than over the East, a nighttime maximum over portions of Argentina, large regions of low amplitude diurnal cycles off the tropical western coasts of continents, and fewer large-scale phase features over the oceans than over the land. Summertime diurnal cycles in surface temperature and evaporation appear to be driven by solar radiation, with afternoon peaks lagging local noon slightly. The diurnal cycle of winds shows a favoring of onshore and upslope flow during the day and offshore downslope flow at night. Peaks in water vapor convergence match many of the regional anomalies observed in the precipitation cycle, suggesting these regions' break from the radiation cycle is due to local dynamics.

In addition to the global analysis/forecast output, we are also running the Regional Spectral Model (RSM), which is a regional counterpart to the SFM (similar physics), over all of the GEWEX Continental-Scale Experiments (CSEs) for the entire CEOP period at 50 km resolution. The lateral boundary conditions for the RSM come from the global RII. The RSM output is also being provided to the Inter-CSE Transferability Study (ICTS), which is focusing on a regional model simulation ensemble over 7 regional domains. The continuous RSM simulations begin Jul. 1, 1999 in order to make sure the RSM land surface has equilibrated by the time we begin our analysis of the CEOP Jul. 1, 2001-Dec. 31, 2004 time period. Defining appropriate model domains, characteristics such as orography at the boundaries of the model domain and inclusion of the characteristic atmospheric processes have to be taken into account and will eventually require additional assessments from other CSE representatives. Techniques, such as spectral nudging and precipitation assimilation as part of the physical initialization, will also be applied and evaluated for each domain. In order to estimate the uncertainty using various global reanalyses for initialization model runs initialized with different analyses (e.g. European and Japanese) are being contemplated.

Meinke et al. (2005) have begun to compare these regional simulations to the in situ observations and various global analyses. First comparisons of the long term simulations versus Global Precipitation Climatology Centre (GPCC) and CEOP reference site data showed that RSM is capable to simulate realistic precipitation patterns all over the seven domains (see Fig. 1). Regarding the differences between simulated and measured precipitation there are similarities between the different domains: Large differences for precipitation are connected with the ITCZ and over shallow orography. Also, the simulated precipitation has higher values than measurements at most CEOP reference sites. Comparisons of the simulated relative humidity versus CEOP reference site measurements show good agreement at most stations. The annual cycle of precipitation and relative humidity also shows largely good agreement between simulated and CEOP data. Differences between

model and data might not only be caused by model deficiencies, but also by uncertainties e.g. of the measurements or the initial state of the model. Thus, the ranges of these uncertainties have to be estimated, first. Model deficiencies can be localized if the differences between model and observations exceed the estimated range of uncertainty. If deficiencies are found, sensitivity studies will need to be carried out to improve the parameterizations.

Research Accomplishments

We hope to further isolate strengths and weaknesses of our global and regional atmospheric models' handling of the diurnal cycle. Our models will most likely have the most trouble with areas dominated by synoptic and mesoscale weather patterns, as opposed to regions dominated by the planetary scale, where monthly means better represent diurnal patterns. That is, we expect differences in the models' ability to handle tropical versus higher latitudes, coastal versus inland areas, mountainous versus flat ground, and desert versus deciduous biomes. For each of these areas, the models' abilities to accurately reproduce a single variable may prove most important (for example land and sea breezes near coastal areas or solar insolation in the desert). Our models' performance may also shed light on the strengths and weaknesses of its convective (and other) parameterizations.
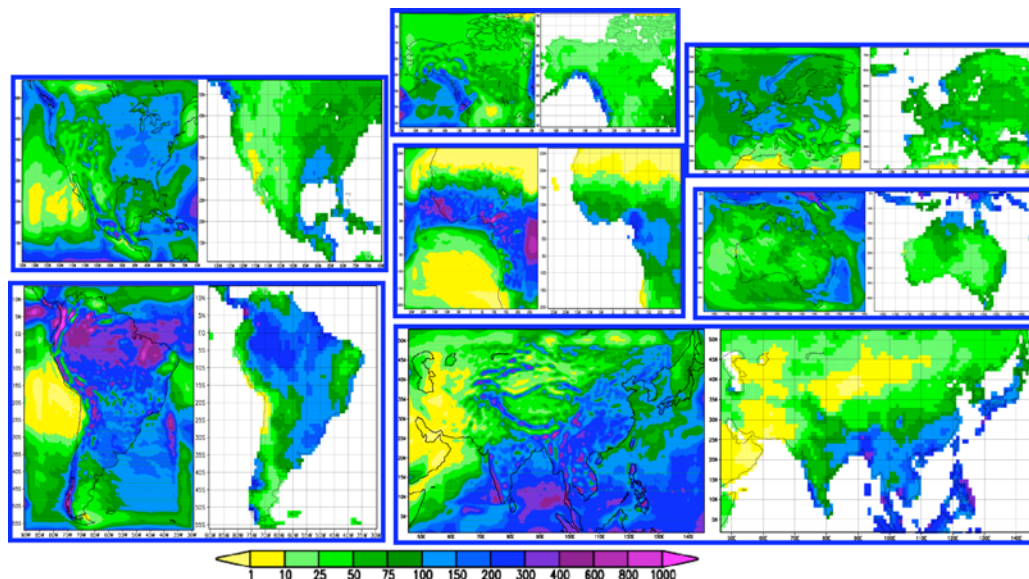

Fig. 1 RSM precipitation (left of each domain) versus GPCC data (right of each domain)

Economic Benefits of Weather and Climate Forecasts to California Energy Production Management

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Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
NOAA Goal 3: Serve Society's Needs for Weather and Water Information

Research Objectives and Specific Plans to Achieve Them

The purpose of this research is to produce weather and climate forecasts tailored to the energy production industry, and to evaluate the economic benefit of those forecasts. We plan to achieve this by assessing the climate related needs of key energy industry decision makers, then producing, evaluating the skill of, and distributing forecasts to address those needs. The results will be given directly to the relevant energy industry personnel in addition to being published in the scientific literature.

Approach, Evaluation and Methodology

The two objectives were broken down into specific tasks, notably:

Objective 1 (produce and evaluate skill of weather and climate forecast variables important to energy supply and demand):
(1)   Assess weather-related issues if important to energy industry
(2)   Identify weather/climate information needed to address these issues
(3)   Produce operational 0-7 day weather forecasts for the energy industry
(4)   Produce 0-14 day hindcasts for energy industry
(5)   Produce seasonal forecasts for the energy industry
(6)   Iterate to produce optimal weather/climate forecasts
(7)   Evaluate the skill of the climate forecasts

Objective 2 (quantify the economic benefit of weather and climate forecasts):
(1)   Identify key weather/energy scenarios
(2)   Evaluate climate connections between California and the Pacific Northwest
(3)   Calculate the economic benefit of various strategies used during the scenarios
(4)   Evaluate the sensitivity of the business forecast to the weather forecast
(5)   Evaluate the economic benefits of the weather-enhanced business forecast

Research Accomplishments

The California Energy Security Project ("CalEnergy") has resulted in four primary accomplishments. First, we produced weather and climate forecasts tailored to energy agencies and utilities, and evaluated the skill of those forecasts. Second, we established collaborative relationships with energy partners, including utilities and government agencies, and identified the types of decisions and the decision-makers that could potentially benefit from these forecasts. Third, we worked directly with users to integrate those forecasts into decision-making, which involved an iterative process of communicating and refining forecasts products to meet user needs. Fourth, we evaluated the net economic benefits of using that forecast information, relative to existing information.

Examples of the forecast projects we have worked on are:

a) Working with the California Independent System Operator (Cal ISO), we calculated that a reduction of forecast error in the California central valley from the current 3.05°F to 2.7°F would reduce weather-related error costs from $10M to $8M/year. We designed a series of statistical correctors to the weather forecast data that are optimized to reduce the biases in the forecasts that incur the greatest costs for them (and, hence, ratepayers). We designed a forecast for likelihood of the "delta breeze" (which greatly influences their electrical load), which is in the process of going operational.

b) We worked with San Diego Gas & Electric to develop a forecast scheme for calling peak load demand management days (days when electrical load is anticipated to be one of the 12 highest days per summer). This scheme nets 6% greater electrical use on forecast days than average days over the period 1990-2003, compared to the maximum possible (based on temperature forecasts) of 12%. This is better than had previously obtained and obtains half the maximum possible.

c) We worked with PacifiCorp (a large utility in the Pacific Northwest) to forecast the total electrical load expected from irrigation pumps over the summer season. We found some skill using soil moisture and precipitation in the spring to forecast this value. This project is ongoing, but we expect this will help them optimize their operational processes.

d) We have estimated that fluctuations in the North Pacific Oscillation (NPO) climate phenomenon can make a $220M difference in residential and commercial natural gas heating bills over the winter.

e) We have developed an extensive set of forecast products for the California Energy Commission, which should help them in their job of steering California's electricity utilities towards ways of operation that have the greatest reliability at the least expense.

Another important outcome of this project has been scientific outreach: By working directly and continuously with potential users of forecast information, we have been able to provide the forecast products that would be most valuable to decision-making, and in turn, user needs have helped to direct the forecast products that were generated. The research has had far reaching significance because weather and climate forecasts provide broad potential to better anticipate and manage fluctuations in energy supplies and demands.
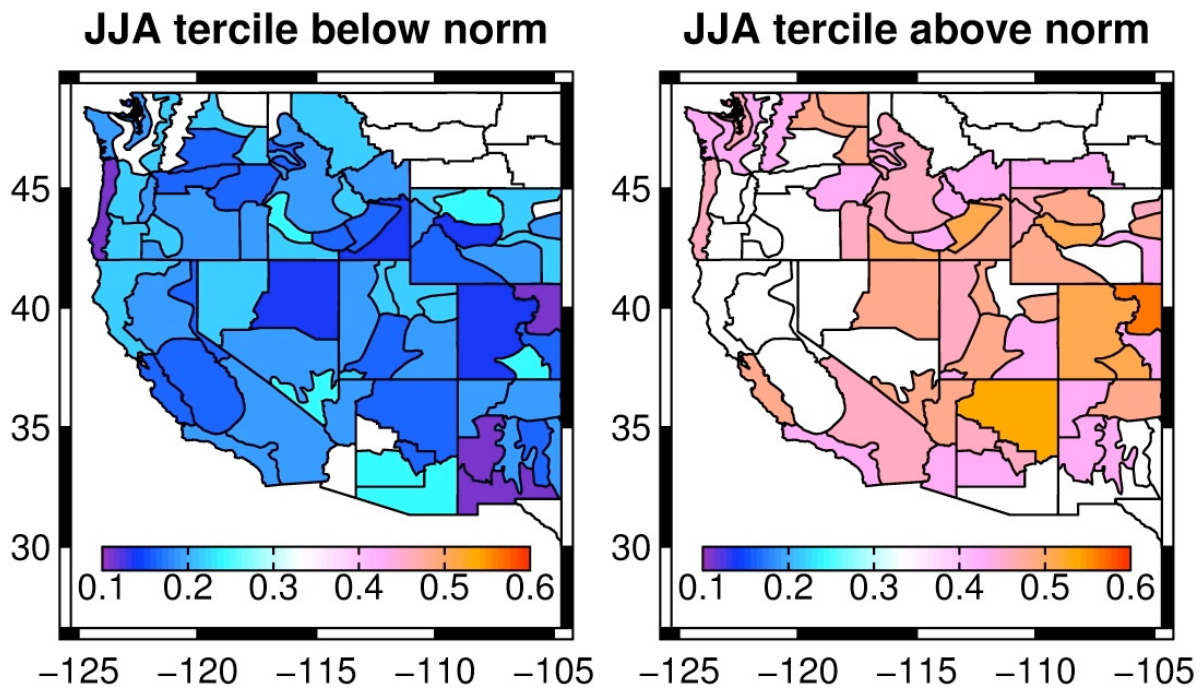

Fig. 1 Given warm temperatures in spring, the figure shows the chance of getting cold (left panel) or warm (right panel) temperatures in summer. Blue colors indicate a low chance, oranges and reds indicate a high chance. This association between spring and summer temperatures forms the basis for predicting summer irrigation pump electrical loads, as described in Alfaro et al., J. Applied Meteorology, 2005.

Seasonal Climate Diagnostics Consortium

John Roads (SIO)

NOAA Technical Contact: Ming Ji (OGP)
Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Research Objectives and Specific Plans to Achieve Them

The goal of the project was to diagnose and improve the skill of the current operational National Centers for Environmental Prediction (NCEP) seasonal forecast model (SFM). We started to archive NCEP SFM forecasts

every day for the past last year and created a large data archive for analysis. The other approach was to produce forecasts following the guidelines provided by IRI, which originated from the predictability efforts finished earlier. In fact while the predictability experiments were underway, several improvements were made to the ECPC version of the NCEP SFM and these improvements may eventually lead to a better seasonal forecast model at NCEP. Finally the SFM has now successfully replaced the Reanalysis II (RII) model used for the NCEP/DOE reanalysis II and the reanalysis has been repeated for the period 1999-2004. Comprehensive products from both of these global analyses have now been provided to the Coordinated Enhanced Observation Period (CEOP) model archive.

Approach, Evaluation and Methodology

Our experimental seasonal forecast system is made up of the two components: 1) a system to perform 1-month continuation of the 10-member ensemble AMIP runs at the beginning of each month using observed SST of the previous month; near real time SST is obtained from NCEP, courtesy of Dr. Wesley Ebisuzaki; 2) 10-member seven-month integrations are then made using predicted SST provided by the International Research Institute (IRI). The forecast results are sent to IRI and NCEP on time for their official issuing of the seasonal outlook forecasts. Fig. 1 shows a diagram of ECPC seasonal forecast system. The quality of the forecasts is being examined at ECPC as well as at IRI. Robertson et al. (2004) showed that the forecast skill is comparable to other models used at IRI and is definitely useful for forecast in various locations in the world.

Nakaegawa and Kanamitsu (2004) linked seasonal forecast skill with the temporal variability of the tropical SST. The temporal variance of the tropical SST has increasing trend, which corresponds well with the increase in forecast skill (Fig. 2). Increasing variance is also examined in various observed and simulated parameters, which showed similar trends in some of the parameters but not all. The relation between increased variance and SST observational coverage is considered to be one of the reasons. Implication of this study is that we need to be cautious about forecast skill and AMIP-type run simulation in very early years (late 1800 to early 1900) when SST observation is sparse.

In order to utilize the ensemble forecasts more efficiently than a simple ensemble average, cluster analysis was applied and we found when the tropical SST forcing is relatively weak, multiple clusters appear in the ensemble, and one of the cluster members has much higher skill than the ensemble mean. When the tropical SST forcing is strong, one dominant cluster appears and the distribution is more normal, and the ensemble mean becomes the best estimate. Nakegawa and Kanamitsu (2005) provides more details.

Research Accomplishments

We now have a state of the art forecast and analysis system that provides not only useful seasonal forecasts but also useful climate diagnostics. We will continue to provide forecasts to the IRI. We will also continue to analyze the NCEP seasonal forecasts to determine if we can develop combination techniques superior to simple ensemble means.
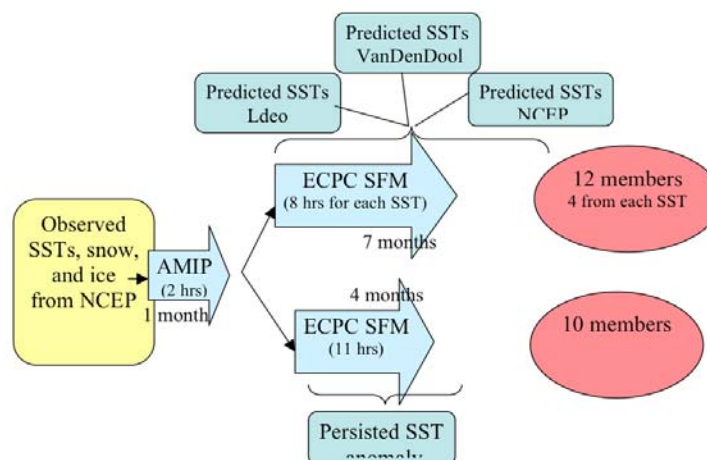

Fig. 1 ECPC Seasonal Forecast System diagram

Times given are with 30 processors. With 60 processors, the entire forecast can be done in approximately 20 hours.

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Temporal Correlation Dif.
500hPa height   DJF

10-year period
GSM run T62L28
7 ensemble members

(a) 1951-60   (b) 1961-70
(c) 1971-80   (d) 1981-90
(e) 1991-2000   (f) 1951-2000 (base ACC)
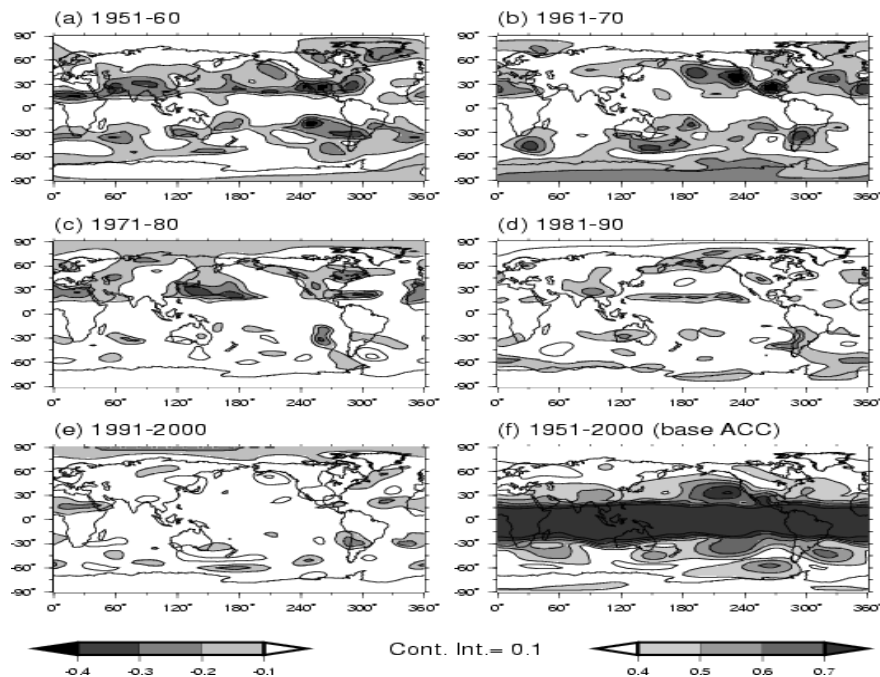
Cont. Int.= 0.1

Fig. 2 500hPa potential temporal correlations coefficients for DJF for each decade in the ensemble experiments. The coefficients in (a) to (e) were subtracted from the temporal correlations coefficients for the period 1951-2000 (f) to emphasize differences

IRI/ARCS Regional Modeling Applications Project

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NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Research Objectives and Specific Plans to Achieve Them

The previous highly focused ARCS/IRI regional modeling intercomparison project centered over Brazil (Roads et al. 2003) evolved toward a larger project with less of a regional focus but with the promise of eventually developing a greater number of regional applications for several additional regions. A lot of effort under this consortium was focused on improving our regional models (Roads 2004) that could eventually be used for regional applications. Improvements included precipitation assimilation and coupling of a regional ocean model to our regional atmospheric model. The major regional application focus was the development of a seasonal fire danger forecasting capability.

Approach, Evaluation and Methodology

1. Precipitation Assimilation
A new CVS version of the RSM has been developed to closely emulate the new Seasonal Forecast Model and this model was used for global change experiments (Han and Roads 2004, Leung et al. 2003, 2004). The new

CVS version will provide a possible methodology for the community to share and test new GSM parameterizations being developed at NCEP in various regions over two distinct domains: (1) North America domain for the Project of Inter-comparison of Regional Climate Simulations (PIRCS), starting on July 1st, 1986 through December 1993 using RAS; and (2) an extended-range simulation covering the beginning of the Large-Scale Biosphere-Atmosphere (LBA) wet season campaign of January 1999 over South America domain, starting on January 1st, 1999, using SAS (Nunes and Roads, 2005). Figure 2 presents a set of precipitation estimates to evaluate the temporal evolution of the regional simulation. Control has the lowest correlation values during the entire simulation.   The mean values are (in mm day-1): 3.70, 4.69, 3.98, 3.86 for PI, Control, SSM/I and 1DD-GPCP, respectively. The average precipitation difference between the Control and the PI simulations is around 1 mm day-1, which is about 26% of the mean "observed" value. PI has the lowest mean value of precipitation, and is closer to the GPCP mean value in comparison to the control experiment.

2. Regional Ocean Model

A regional coupled atmospheric-ocean model is being developed in order to better understand air-sea interactions in the eastern North Pacific Ocean and California coastal region and eventually develop ocean applications. The atmospheric part of the coupled model is the RSM, which is nested within the GSM (200 km resolution). The oceanic component is the eddy resolving Regional Ocean Modeling System (ROMS) that utilizes a generalized sigma-coordinate system in the vertical and a curvilinear horizontal grid (12 km resolution) along with real bottom topography and coastlines. We have begun one-way coupling experiments in order to understand the characteristic response of RSM to oceanic forcings and ROMS to atmospheric forcings. The RSM provides 3 hourly forcings to ROMS. The momentum and buoyancy fluxes used to force ROMS at the upper boundary were initially calculated directly from RSM simulation. Our preliminary simulation for the year of 2003 indicates that simulated area-averaged SST with flux correction was warmer than observed SST by around 0.4 degree C. Monthly mean momentum fluxes (yellow) are very close to monthly climatologies (green, blue), but clearly provide daily and diurnal fluctuations (red). We were able to subsequently use these 3-hourly varying forcings to force the ocean model in order to examine diurnal response of ocean state to atmospheric forcing as well as seasonal cycle of the current system. Preliminary simulations for the year of 2003 show the reasonable seasonal evolutions of the Surface Coastal Current System (SCCS). The next step will be to use diurnally varying SST fields from ROMS to force RSM at the lower boundary, which is normally forced with coarse-resolution analysis or climatological SST. Rather than directly using the RSM fluxes, we believe, however, that the model will be more stable if we use the bulk parameterization to provide feedback between air and sea. Currently, ROMS uses bulk formula that are adapted from Coupled Ocean-Atmosphere Response Experiment (COARE) and computes surface fluxes given the atmospheric boundary layer variables.

3. Fire Danger

Predicting the influence of weather on fire ignition and spread is an operational requirement for US and global fire planning by the US National Interagency Coordination Center (NICC), which is the US's support center for wildland firefighting. NICC's Predictive Services produces national wildland fire outlook and assessment products at weekly to seasonal time scales. This is currently done by considering standard National Weather Service seasonal forecast products of temperature and precipitation (see Brown et al. 2003) along with other indicators, and carefully exercised human judgment. We have therefore been making (Roads et al. 2005) experimental, near real-time, weekly to seasonal fire danger forecasts for the past 5 years. US fire danger forecasts and validations are based on standard indices from the National Fire Danger Rating System (NFDRS), which include the: Ignition Component (IC), Energy Release component (ER), Burning Index (BI), Spread Component (SC), and the Keetch Byram drought index (KB). The Fosberg Fire Weather Index (FWI), which is a simplified form of the BI, has been previously used not only for the US but also for other global regions and is thus included for comparison. As shown in Figure 1, all of these indices can be predicted well at weekly times scales and there is significant skill out to seasonal time scales over many US West locations. The most persistent indices (BI and ER) tend to have the greatest seasonal forecast skill. The NFDRS indices also have a weak relation to observed fire characteristics such as fire counts (CN) and acres burned (AC), especially when the validation fire danger indices are used. Reinhold et al. (2004, 2005) further assessed our RSM predictions in comparison to western US Remote Automated Weather Station (RAWS) observations. Fire danger indices had much lower correlations, but did show useful spatial structure in some areas such as Southern California, Arizona, and Nevada.

Research Accomplishments

Although the ECPC has focused previously on seasonal predictions, we are now moving into regional simulations and applications of global change predictions as part of a request by the NOAA Regional Integrated Sciences and Assessments (RISA) Activity, California Application Program (CAP) and California Energy Commission (CEC). We were subsequently requested to join the North American Regional Climate Change Assessment Program (NARCCAP), in part because of our previous effort to provide similar downscaled simulations for the DOE Accelerated Climate Prediction Initiative (Han and Roads 2004, Leung et al. 2003, 2004), in part because we provide unique regional climate modeling capability, and in part because of our ongoing contribution to the CAP/CEC effort. NARCCAP is proposed to be a multi-agency effort and ECPC has been requested to provide the NOAA contribution.
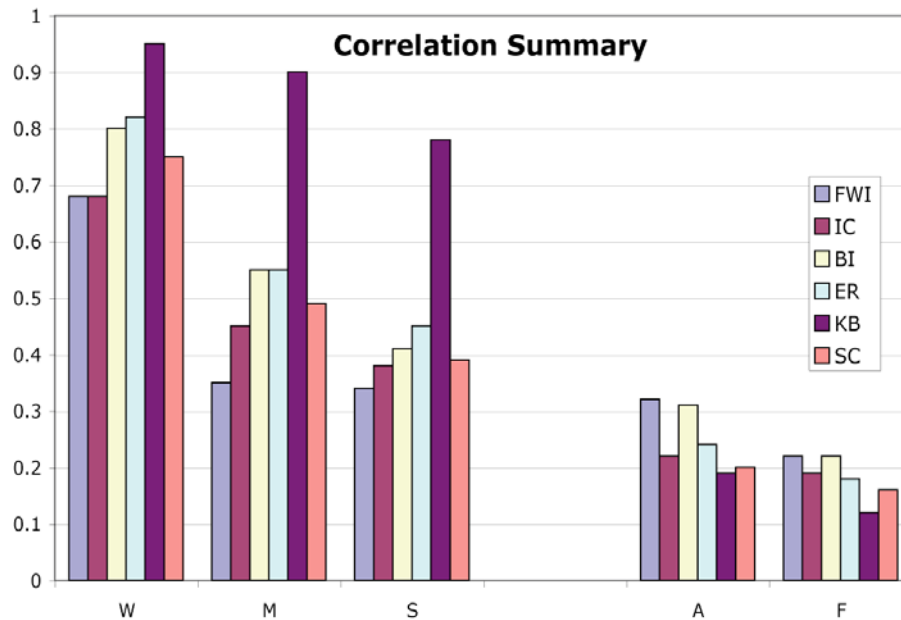

Fig. 1 Summary forecast skill for weekly (W), monthly (M), seasonal (S) forecasts of FWI, IC, BI, ER, KB, SC in comparison to the validating analysis. Also shown are the correlations of seasonal means of the validating analysis (A) and seasonal forecasts (F) for these same indices with the seasonal mean AC.
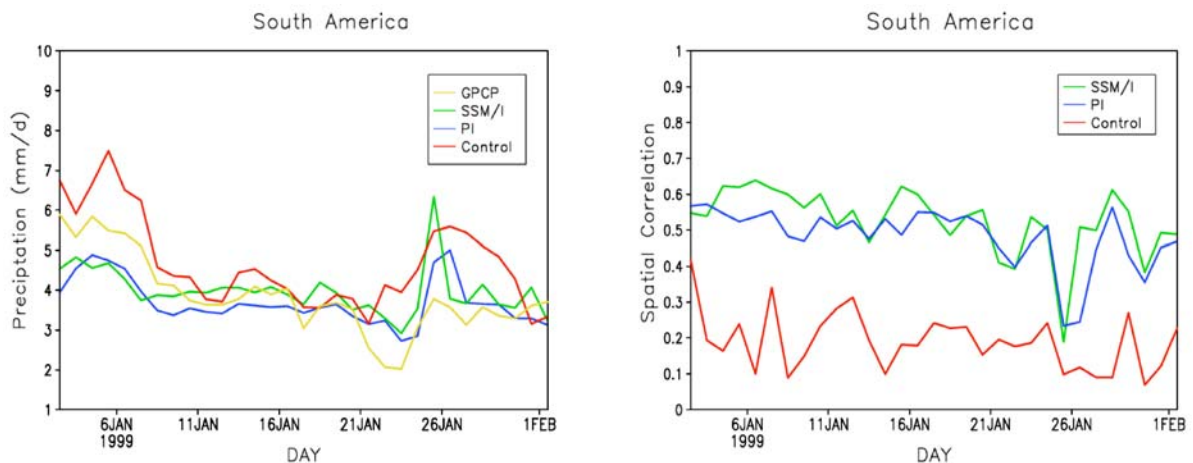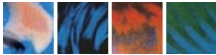

Fig. 2 Temporal evolution during January 1999 over South America of: (a) daily precipitation values (mm/d), and (b) spatial correlation coefficients (PI, Control, and SMM/I versus GPCP). The blue curve indicates PI experiment, the red curve represents Control, the green shows the SSM/I-OLR estimates, and the yellow curve correspond to 1DD-GPCP daily values.

SIO's Participation in US GODAE: Sustained Global Ocean State Estimation for Scientific and Practical Application

Dean Roemmich, Bruce Cornuelle and Russ Davis (SIO)

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Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Research Objectives and Specific Plans to Achieve Them

The SIO role in GODAE provides the direct linkage between Argo and other *in situ* ocean observational elements with the modeling and assimilation elements of the GODAE consortium. The use of Argo float profiles is a major GODAE activity. As with any new data set there are many issues to be confronted for successful use of the data, and the SIO responsibility is to provide the required knowledge of datasets and expertise with instrumentation. The SIO group also serves as an interface between assimilation activities and CLIVAR science.

Approach, Evaluation and Methodology

The ocean research carried out under CLIVAR involves three types of work with ocean data:

- improvement in seasonal-interannual climate forecasting, including investigation of initialization of the ocean in forecast models.
- interpretation of field process experiments focused on improving the representation in models of ocean processes.
- analyses of observed climate variability with an ocean focus on individual basins. Our goal is to use ocean state estimates (or ocean re-analyses) to explore the dynamical processes behind the observed variability.

Research Accomplishments

- Graduate student J. Willis, advised by PIs D Roemmich and B Cornuelle, implemented a simplified (quasi-geostrophic) data assimilation model in order to understand the impact of in situ profile data on the assimilation system and to study the limits on predictability of the mesoscale eddy field in the central North Pacific Ocean. Following his graduation, Dr. Willis began a post-doc at NASA/JPL, where he links the SIO effort to that of ECCO consortium partners at JPL.
- Graduate student E. Douglass, advised by PI D. Roemmich and collaborator D Stammer, carried out a study of interannual variability in the circulation of the northeast Pacific, analyzing high resolution datasets jointly with output from the ECCO data assimilation model. This work has been submitted for publication and provisionally accepted. Ms Douglass is expanding her study, and is now running a high resolution version of the ECCO model in the Pacific, nested in the global low resolution model. The goals of this study are first to improve the impact of data in the assimilation system and second to study processes responsible for meridional transport of heat in the North Pacific.
- Specialist J. Gilson developed a graphical user interface (GUI) which allows Argo salinity experts to carry out scientific quality control of Argo data. The system enables a user to display sequences of profiles from a instrument, and compares them to climatological estimates, to nearby research vessel CTD data, and to nearby Argo data from other instruments. The Gilson GUI has been adopted by international Argo partners, and work is now proceeding to process the existing backlog of Argo profiles for research applications. This work has great benefits for GODAE because it will provide a self-consistent and high quality Argo dataset suitable for GODAE.
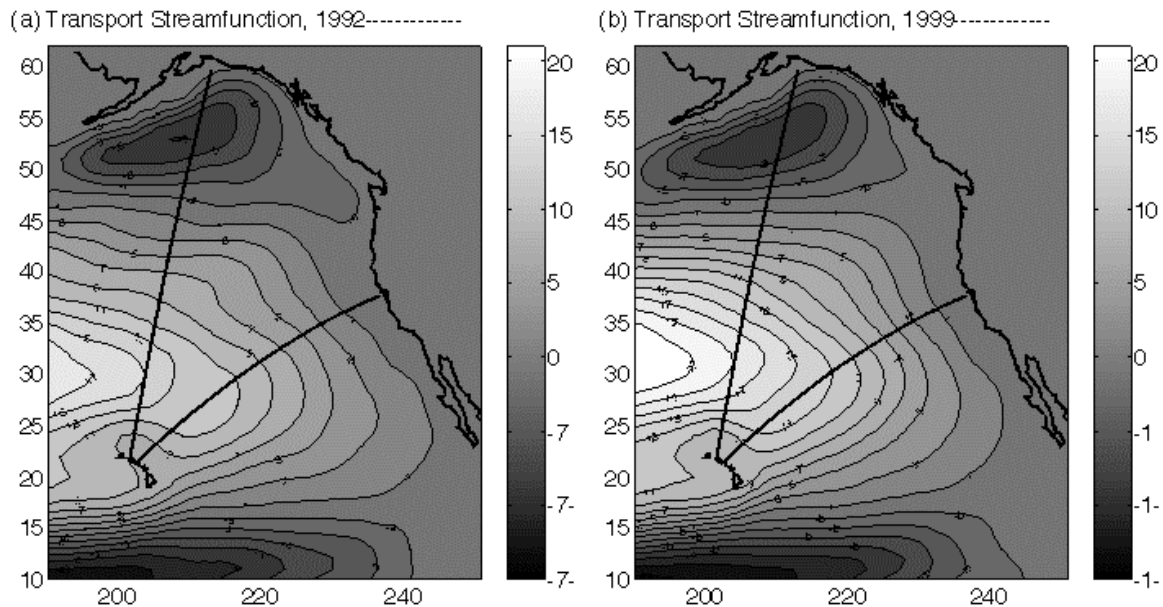
Fig. 1 Transport streamfunction (contour interval = 2 x 106 m3s-1), based on the ECCO model and High Resolution XBT lines, for two 4-year periods before and after the 1998 increase in the North Pacific Current.

Multi-Column Continuous Flow Streamwise Thermal-Gradient CCN Chamber / Asian-Pacific CCN Network for Studying the Aerosol Indirect Effect

Greg Roberts and V. Ramanathan (SIO)

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NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Research Objectives and Specific Plans to Achieve Them

Measurements of cloud condensation nuclei (CCN) are fundamental for providing the link between cloud microphysics and the physical and chemical properties of aerosol. Significant improvements in the measurement techniques are needed and the continuous-flow streamwise thermal-gradient technique (Roberts and Nenes, Aerosol Sci. Tech., 2005) has provided high quality CCN measurements on the ground as well as on airborne platforms. The prototype instruments were flown on the CIRPAS Twin Otter during CRYSTAL/FACE (Van Reken et al., J. Geophys. Res., 2003). The DMT (Droplet Measurement Technologies) commercial version was first flown during the Cloud-Indirect Forcing Experiment (CIFEX) and has since been successfully deployed in several international airborne and ground-based experiments.

The use of a single column will generate CCN spectra, by modifying the flow rate and temperature gradient; however, not at a time resolution sufficient for airborne measurements. The purpose of this project is to transform our single-column CCN instrument into a compact, automated multi-column device to retrieve CCN spectra over a range of supersaturations important for aerosol/cloud interactions. CCN spectra are important, especially for airborne measurements as supersaturations change spatially and temporally in different parts of the cloud. The multi-column CCN instrument will provide 1 Hz measurements at five supersaturations between 0.1% and 1.0%.

Approach, Evaluation and Methodology

To avoid complications originating from unexpected instrument performance (i.e., buoyancy effects and non-linear temperature profiles), we have identified the operational limits of the streamwise CCN instrument. Theory and model simulations have been developed to optimize design and operating conditions of the CCN chamber. These calculations ensure proper performance and enable us to reduce the overall size of the instrument – making the multi-column device easier for field deployment and compatible with various aircraft. These results have been used to develop a computer-aided design package (Figure 2) before starting construction of the instrument. Building on earlier versions, the inlet and optical particle counter have been modified, miniaturized and optimized for CCN measurements.

Research Accomplishments

The single-column prototype instruments were flown on the CIRPAS Twin Otter during CRYSTAL/FACE [Van Reken et al., 2003]. The DMT commercial version was first flown during the Cloud-Indirect Forcing Experiment (CIFEX) and has since been successfully deployed in several airborne and ground-based measurements, including the 2004 NOAA/ICARTT (International Consortium for Atmospheric Research on Transport and Transformation) and ABC (Atmospheric Brown Cloud) Experiments.

Through model simulations and optimizing the design, the size of the single-column CCN instrument has been reduced from a commercial instrument of 80 x 50 x 30 cm and 28 kg to a smaller package of 20 x 10 x 10 cm and 2 kg (Figure 2) without compromising its performance. This design will be used for the construction of the multi-column package, which will be completed in 2005, culminating in airborne measurements during the MIRAGE experiment by early 2006.
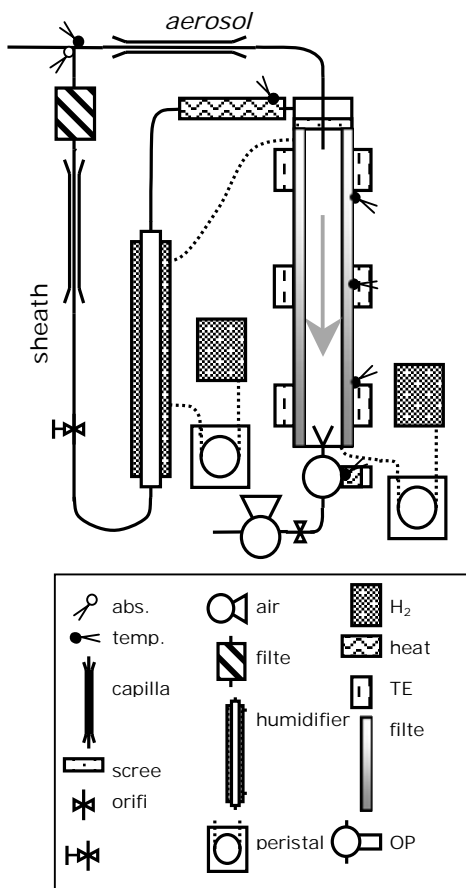

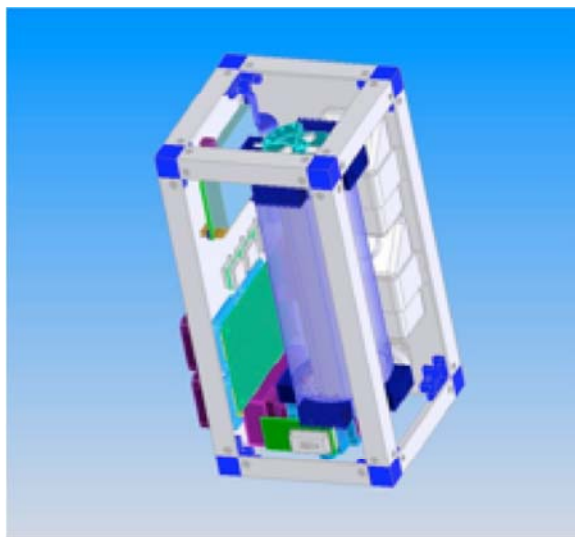Fig 1. Schematic of single column CCN chamber

Fig. 2 Optimized single-column design that will be extended to multi-column package

Global Model Investigation of Warm Season Precipitation for North American Monsoon Experiment

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Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Research Objectives and Specific Plans to Achieve Them

The scientific goal of our research is to understand the interplay between the North American monsoon convection and the seasonally varying mean climate. The research addresses the following fundamental scientific issues highly relevant to the modeling component of the PACS/GAPP North American Warm Season Precipitation Initiative:

• Global model simulation of the seasonal evolution of the North American monsoon system.
• Simulation of the diurnal cycle of convection and its relationship to seasonally varying mean climate.

Approach, Evaluation and Methodology

The project focuses on the modeling component of the North American Monsoon Experiment (NAME). Through carefully designed numerical experiments, multi-year CCM3 simulations were performed to composite the diurnal cycle of convection and associated dynamic and thermodynamic conditions. The composite structure of circulation, precipitation and hydrological cycle are compared with observational results to determine systematic differences between model and observations.

Research Accomplishments

We made significant progress last year in evaluating the ability of the NCAR CCM3 in simulating the evolution of the North American Monsoon system. Dr. Craig Collier joined our team last summer to work with the PI on this project. We carried out two sets of 9-year (1994 to 2002) model integrations using the NCAR CCM3, with observed sea surface temperature as the lower boundary condition. One uses the standard CCM3, and the other uses the new convection parameterization closure developed by the PI (Zhang, 2002). Each set is equivalent to an ensemble simulation of the summer monsoon season climate. Our objective is to evaluate the evolution of the simulated summer season precipitation in the North American Monsoon region and its sensitivity to convective parameterization.

Fig. 1 shows the monthly mean precipitation rates over the US southwestern states during the warm season (May, June, July, August and September) from CCM3 simulations and the surface gauge observations. During May and June, precipitation is aligned north south over the Great Plains. By July, precipitation extends southwestward to Arizona and New Mexico. Compared to the gauge observations, the standard CCM3 model produces excessive precipitation in the western Great Plains in all months, particularly in June and July. The experiment with a new convection parameterization closure gives a much-improved simulation of the precipitation intensity. It also simulates the monsoon precipitation in Arizona and New Mexico during July and August.

The upper tropospheric moisture is another measure of the simulation of convection, because it reflects the vertical transport of moisture by convection. Fig. 2 shows the specific humidity and wind distribution at 300 mb during the warm season from the two CCM3 simulations and the NCEP/NCAR reanalysis. Both the simulations seem to capture the general pattern of the circulation well. However, in the moisture field the standard model run is too moist south of 30ºN throughout the summer. During July and August, there is also a significant moist bias near 40ºN, corresponding to excessive convection over this region. The moisture distribution in the experimental run with the new convection closure is in excellent agreement with the NCEP/NCAR reanalysis throughout the warm season.

In addition to the NCAR CCM3 simulations, we also actively participated in the model intercomparison activities led by Siegfried Schubert of NASA, involving the NCAR model, GFDL model and NASA model. Through a number of conference calls with participants from NASA, GFDL, NCEP and SIO, we exchanged data information and preliminary results. This is proven beneficial to the community in understanding the capabilities of the global model in simulating the North American Monsoon system.
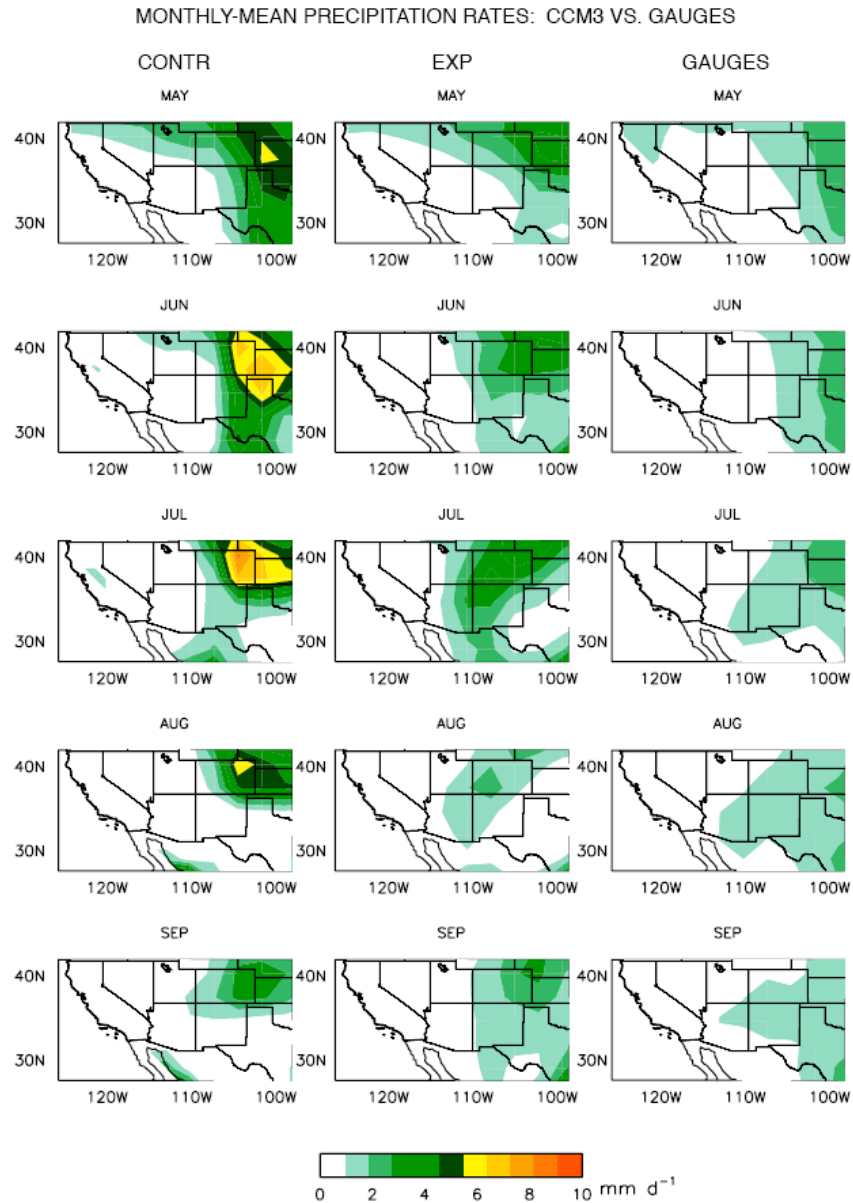
Fig. 1: Monthly-mean precipitation from standard CCM3 (left), CCM3 with a new convection parameterization closure (middle) and surface gauge observations (right), averaged over years 1994-2002 for the warm season May-September.

300-MB SPECIFIC HUMIDITY AND WINDS: CCM3 V. NCEP-NCAR REANALYSIS
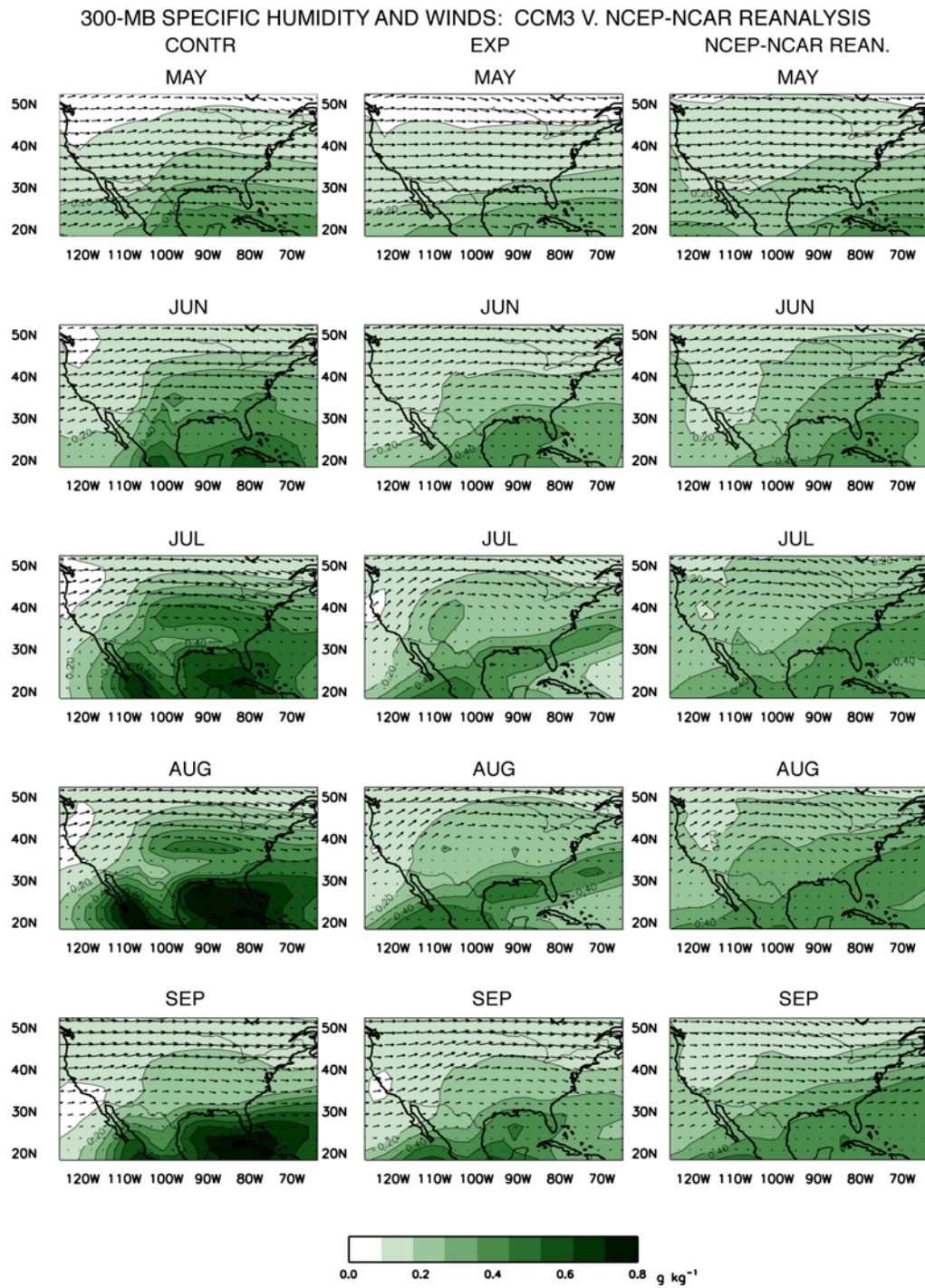
Fig. 2: Monthly-mean 300 mb specific humidity and horizontal winds for CCM3 CONTR (left), CCM3 EXP (center), and NCEP-NCAR reanalysis (right), averaged over years 1994-2002.

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NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Research Objectives and Specific Plans to Achieve Them

Our principal objective is to develop a quasi-continuous, comprehensive reconstruction of the El Niño phenomenon over the last millennium by using the climate record of fossil corals. Our strategy is to analyze an existing collection of fossil coral records from Palmyra Island (central tropical Pacific), whose ages span the last 1200 years. Though any one individual coral record is only 50-100 years in duration, the records may be spliced together to create an extended time series, with approximately monthly resolution. We also seek to fill in and replicate (or simply test the reproducibility of) the Palmyra reconstruction by collecting analogous observations from other coral atolls in the central Pacific, including Christmas Island (2°N) and Fanning Island (4°N). Once in place, and the uncertainties in the reconstruction quantified, we can characterize the evolution of ENSO with unprecedented detail. We will also come away with an estimate of mean (century scale average) climate state in the central tropical Pacific over the last millennium.

Approach, Evaluation and Methodology

In this first year of the project, we continued to analyze the stable isotopic composition of the fossil corals that we had already collected from Palmyra Island. We focused on splicing records from the 13th century and generating an extended record from the 11th century. We confirmed the reproducibility of the analyses in multiple corals. This work entailed approximately 3500 individual stable isotope measurements.
We also planned a field excursion to Christmas Island to collect fossil coral cores that would substantiate and/or fill in the gaps of the Palmyra collection. This trip had to be postponed twice, for different reasons entirely out of our control.

In the second year of the project, a two-person team (P.I. Charles and technician Jordan Watson) carried out the sampling trip to Christmas Island (August, 2004). Though curtailed because of transportation issues, the trip was a success. 10 high quality coral cores were collected from the fossil coral deposits on the southwest facing beaches of the island. We are still in the process of analyzing this material, but initial radiometric dates on the cores suggest that they all lie between 100-600 years old. Thus, they will prove to be an excellent counterpart to the Palmyra coral collection. Given the young age and the elevation and extent of these deposits above mean sea level, it is very likely that the large corals were washed ashore by tsunami events. A few more days of searching would undoubtedly yield many more coral cores. In May, 2005, a four person team (Res. Assoc. Kim Cobb, technician Watson, grad. student Jessica Carrilli and an undergraduate observer) carried out an analogous sampling trip to Fanning Island, where numerous long coral heads were drilled, some extending continuously for over 80 years. Initial radiometric dates on two of the longest cores suggest that they are much older than the Palmyra and Christmas deposits: they are mid-Holocene in age. Thus, this material should give us a tremendously valuable window into the dynamics of the ENSO phenomenon over the Holocene.
A third trip to three of the Line Islands (Christmas, Fanning and Palmyra) is now also scheduled for August, 2005. This trip will serve as the final field campaign for this project and is necessary to collect the remaining cores that we did not have time to take during our first visit(s) to each island.

In the second year of laboratory work, we have analyzed the oxygen isotopes in one 50 year long sequence from one of the Christmas Island cores at monthly resolution. We have also analyzed a 45 year long sequence from Fanning Island. We have also continued to work our way through the existing Palmyra cores, focusing on the cores from the 16th-17th century. Thus far, in two years, we have completed more than 6000 stable isotopic measurements, but we will continue to work through the different collections throughout the remainder of the project. We will also obtain U/Th dates from the Christmas Island cores.

Research Accomplishments

As a result of our continued laboratory work in the first two years, we are very close to creating a continuous time series of the ENSO phenomenon, that extends from 1050-1500 AD, at monthly resolution. The notable feature of this reconstruction is that it shows evidence for strong changes in the characteristics of ENSO, ranging from extended episodes of low-amplitude (even non-existent) events, to extended episodes of regular 5-year warm event recurrence. This record from the first half of the last millennium complements other previously analyzed windows available from the 17th century and 19th and 20th centuries. We have also successfully demonstrated the reproducibility of the coral splicing approach, at least at one important location. We have also obtained a high quality suite of fossil coral cores from Christmas Island, a site that lies in the heart of the ENSO anomaly field. At least one of these fossil coral sequences from Christmas Island resembles qualitatively the modern coral record from Christmas Island (Evans et al, 1998).

In total, the analysis to date suggests a clear "regime-like" behavior of ENSO. This non-stationarity is evident throughout the record, and the characteristics of ENSO thus far show little correlation with other indicators of global climate.

Forecasting Climate Changes over North America from Predictions of Ocean Mixed Layer Anomalies in the Tropical and Mid-latitude Pacific

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NOAA Technical Contact: Linda Prevas (OGP)
Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
NOAA Goal 3: Serve Society's Needs for Weather and Water Information

Research Objectives and Specific Plans to Achieve Them

Our research explores the underlying physics and skill of a two-tiered prediction system for climate anomalies over North America for lead times of seasons to years. In contrast to the traditional approach that forecasts anomalies of SST, the first tier of this system predicts anomalies of the oceanic heat flux convergences in areas where the surface ocean is impacted by predictable subsurface variability, namely in the tropics and in the Kuroshio-Oyashio extension (KOE) region. The second tier forecasts associated anomalies of the global atmosphere and, in particular, of climate over North America by forcing a coupled atmospheric general circulation/slab ocean model (AGCM/SOM) with surface heat budget anomalies obtained during the first phase. In order to achieve these objectives we performed the following numerical experiments.
1. Determined anomalous ocean heat flux convergence over the Kuroshio Extension and equatorial Pacific regions by diagnosing the air-sea heat flux of the MIT 1°x1° ocean model forced with NCAR/NCEP reanalysis wind stress anomalies, while relaxing SST to climatology.
2. Forced the coupled AGCM-slab ocean model (CCM3/SOM) with the heat flux convergence anomalies. Run 5-member ensemble integrations from January 1960 to December 1999, with the forcing in (A) both KOE and tropical Pacific regions, and (B) in the tropical Pacific only.

Approach, Evaluation and Methodology

The output from the second tier of the prediction system was analyzed by performing multivariate regression onto four heat flux convergence indices: (1) oceanic heat flux convergence averaged over the KOE region and (2-4) first three principal components of the oceanic heat flux convergence anomalies in the tropics. The corresponding regression maps showed the coupled system response to the forcing in different regions. The comparison with the model (B) revealed the non-linear effect of the mid-latitude forcing. The daily model output was analyzed and the role of the transient eddies in maintaining the response patterns was investigated.

Research Accomplishments

The hindcast experiments with the two-tiered prediction system revealed that the low frequency ocean heat flux convergences in the Kuroshio extension region influence the climate over the North Pacific and North America. In addition to causing a systematic response in the mean atmospheric flow, the anomalous oceanic heat fluxes convergences in the KOE region also lead to the changes in the transient eddies that can be seen in the shift of the location of the storm track over the North Pacific.

The most common way to show the location of the storm track is by displaying the root mean square (RMS) of the band pass filtered anomalies of the 200 mb height (Z200). The RMS of the band pass filtered anomalies of Z200 were obtained as follows. The daily mean values of Z200 were band passed filtered so that the frequencies longer than 6 days were filtered out. The RMS for each day was then obtained. The monthly mean values were then calculated, and climatology was subtracted. Figure 1 shows the regression of the values obtained by the procedure described above onto the KOE heat flux convergence anomalies index. The figure shows the almost uniform north-south dipole with the positive values north of 45N, and negative values equator wards of 45N. This distribution can be also described as poleward shift of the storm track location. The lower panel of the same figure shows the corresponding changes in the zonal velocity of the mean flow. The changes are characterized by strong westward anomalies centered at around 30 N and accompanied by eastward anomalies poleward of 45N.

Eliassen-Palm (E-P) flux is considered to be a useful way of measuring the transient eddy forcing onto the mean flow. The regression map of the simulated E-P flux divergence onto the heat flux convergence anomalies averaged over the KOE region revealed that over central and western North Pacific, the divergence of the EP fluxes of the bandpass filtered synoptic eddies is negative in the belt between 30N and 45 N and positive north of 45N, indicating that transient eddies induce westward acceleration south of 45N and eastward acceleration north of 45N (see Figure 2). Another strong center of action of the synoptic eddies is located along the west coast of North America.

The transient eddies vorticity fluxes reach maximum in the upper troposphere, thus we explored the established vorticity balance of the mean flow at the 200 mb level.
The importance of transient eddy divergent vorticity flux becomes more apparent if the focus is changed to the planetary scales by examining the mean stream function balance. By converting the vorticity equation to the stream function equation we effectively filter out the small scale noise. The analysis of Z200 balance showed the following:

- The mean advection causes negative geopotential tendencies in the east North Pacific and over North America, and positive tendencies over western North Pacific.
- The transient eddies induce almost zonally symmetric positive tendencies over the broad belt between 30N and 60N.
- The tendencies due to divergence of the mean flow is of the opposite sign and has maximum amplitude over North America.

Thus, the simulated Z200 response to the oceanic forcing is maintained by the balance between the positive anomalies induced by the eddy forcing and the anomalies caused by the advection and divergence of the mean flow.

The role of the transient eddy forcing in the lower troposphere is better described by the study of the thermodynamical balance at 800 mb where the diabatic heat caused by the heat fluxes reaches its maxima. The diabatic heating causes positive temperature tendencies over the heating region and negative temperature tendencies southeast of it. The corresponding mean flow advection induces the temperature tendencies of the opposite sign over the KOE region and over central North Pacific. The transient eddies induce a positive feedback over most of the North Pacific in between 30N and 50N. The sign of the temperature tendencies caused by the transient eddy forcing can be explained from the distribution of the meridional temperature advection by transient eddies (Figure 2 lower panel). The negative eddy heat transport south of 40N and positive heat transport north of 40 N result in the positive temperature tendencies at around 40N.

In summary, our research showed that the transient eddy forcing is crucial in maintaining the simulated mean flow variability. North American climate undergoes fluctuations on interannual-to-decadal time scales, with significant changes in precipitation, surface temperature and geopotential height changes as well as in river run-off, agricultural output and Pacific fishery. Thus it is very important to understand the physical mechanism of the

climate response to the predictable oceanic signal. The investigation of the role of the transient eddy forcing in establishing and maintaining the atmospheric response to the low frequency variability is crucial for making possible the long term predictions of climate over North America that are desirable and potentially beneficial for society. Therefore, all forecast systems should correctly represent/resolve transient eddies in mid latitudes.
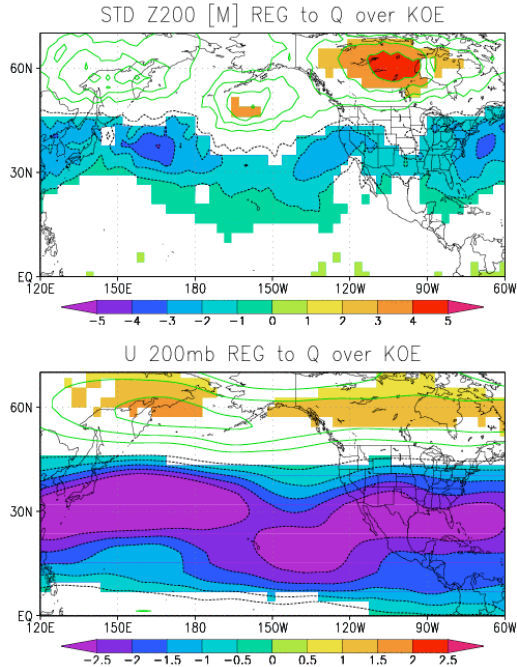
Fig. 1 Upper panel: Regression map of the root mean square of the band pass filtered anomalies (signal with period larger than 6 days is filtered out) of the 200 mb height (Z200) onto the KOE index, measured in M. Lower panel: Same as upper panel, but for the unfiltered zonal velocity of the mean flow, measured in M/S
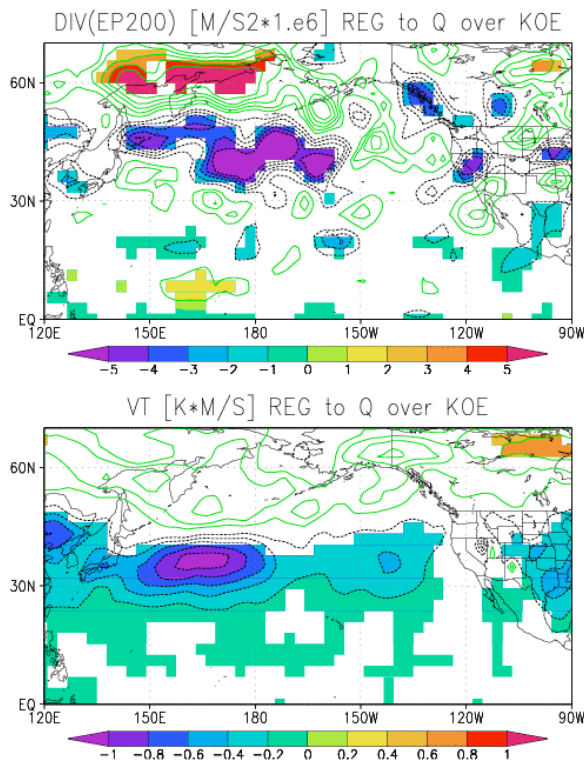
Fig. 2 Upper panel: The regression map of the simulated E-P flux divergence at 200 mb onto the heat flux convergence anomalies averaged over the KOE region. Units M/S2*1E6. Lower panel: same as upper, but for the meridional temperature advection by transient eddies. Units K*M/S.
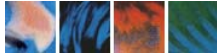
California Applications Program (CAP)

Daniel R. Cayan (SIO)

NOAA Technical Contact: Harvey Hill (OGP)
Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance
Society's Ability to Plan and Respond

Research Objectives and Specific Plans to Achieve Them

The goal of CAP is to investigate the physical climate system and its regional impacts in an integrated way so as to provide useful climate information to decision makers (planners, managers, and information users) in the California region. CAP's organizing philosophy includes three key elements: 1) a focus on representative key and relevant regional climate issues (water, wildfire, human health, and building a regional climate data capacity); 2) an emphasis on improved forecasts and improved reliance on forecasts at seasonal, interannual and long-term time scales; and 3) a core team of authoritative disciplinary researchers experienced/adept at linking across disciplines and enlisting a select small set of motivated and fairly high level practitioners in the applications community

Approach, Evaluation and Methodology

The CAP regional climate studies are being conducted with a mind toward regionally important problems that are affected by global climate influences. Thrust areas identified were chosen for their great relevance to decision makers and residents of California and the greater California region. There are two underlying questions that are common issues across virtually all of the components of this work:

1) Can we identify climate and hydrologic predictive skill at a range of time scales? How can this skill be exploited to the benefit of the water, wildfire and human health sectors?
2) What climate information is needed to inform decision makers in the water, wildfire and human health sectors?

Activities of the three elements (water resources, wildfire and human health) are outlined below. Key components of the activities are also outlined below (forecast methods, regional modeling, and building climate observation capacity). Several of these activities capitalize upon activities that are supported or commissioned by other agencies or collaborators; this exemplifies the connectedness that is being developed at CAP.

Water Resources
Northern California Regional Water Resource Prediction and Management
  K. Georgakakos (HRC), N. Graham (HRC), S. Taylor (HRC), T. Carpenter (HRC), D. Cayan (SIO)
    Testing of a regional distributed hydrologic model (resolution of 200-400 km2) has begun over a target region of the Sacramento River basin in northern California with an outlet point downstream of the confluence with the American River. A potential theory airflow model, coupled to a simplified microphysical rainfall production model, has been developed and tested for representation of the deterministic signal of the orographic rainfall enhancement caused by the terrain of northern California (article in preparation)
Coastal California Surface and Ground Water Resources
  R. Hanson (USGS), M. Dettinger (USGS)
    Using existing regional ground-water models (RGWMs), work has begun assessing the statistical skill of employing GCM weather forecasts at 3 to 6 months into the future. In collaboration with CAP scientists K. Georgakakos and A. Gershunov, work has begun on incorporating statistical downscaling techniques to bridge the gap between the GCMs and RGWMs.
Injecting Climate Knowledge and Research into CALFED
  M. Dettinger (USGS), D. Cayan (SIO), K. Redmond (DRI)
    Assessment of the current state of knowledge about California's climate (as applies to CALFED) and recommendations for climate-science activities and support within the CALFED program has begun. Characterizations of climate variations from paleoclimate proxies, the historical period and in recent

climate-change projections are being formulated for communication to CALFED participants and the public (AMS proceedings paper).

Wildfire

Seasonal Forecasting and Economic Assessments

A. Westerling (SIO), D. Cayan (SIO)

Progress continues on decision calendars for wildfire and fuels management (with B. Morehouse, CLIMAS, and T. Corringham, SIO). Efforts have begun on incorporating climate assessments in long-range fire management plans. A database of individual fire records is being designed to examine fire suppression effectiveness in contribution to the CEFA initiative to develop and evaluate a climate/weather index for escaped fires in California. With M. Dettinger (USGS), T. Brown (DRI), B. Hall (DRI) and L. Riddle (SIO), a Santa Ana wind index was developed and applied for temporal variability and impact on autumn wildfires in southern California (EOS, in press).

CEFA California Activities

T. Brown (DRI), B. Hall (DRI), A. Westerling (SIO), D. Cayan (SIO)

Evaluation and verification of ECPC weekly to seasonal climate forecast fire weather variables and outreach to GACC fire weather meteorologists for assistance in utilizing monthly and seasonal climate forecasts in operations continues. Research collaborations with SIO, CLIMAS and other RISAs progresses and fire climate workshops have been planned.

Human Health

Encephalitis (presently funded by OGPP Joint Program on Climate Variability and Human Health effort)

B. Reisen (UCD), B. Eldridge (UCD), C. Barker (UCD), D. Cayan (SIO), M. Dettinger (SIO)

This research focuses on how climate variability impacts the temporal and spatial dynamics of vector mosquito populations and the pathogens they transmit. A near-complete assemblage of over 3 million trap nights of data are being examined for relationships among climate variability, mosquito abundance and the activity of WEE and SLE viruses. Initial efforts to forecast the risk of virus transmission that may impact the health of California residents has begun.

Building Capacity for Climate Forecasts and Observational Data

Improving Forecasting Methodology

D. Cayan (SIO), M. Dettinger (USGS), A. Gershunov (SIO), A. Westerling (SIO)

Design has begun on a toolkit of techniques to be applied to regional forecast problems. This toolkit includes hybrid statistical/dynamical methods which have focused on hydrological variables but will be applied to other problems, including wildfire and mosquito populations. Work has also begun on another element of the toolkit which handles heavy-tailed distributions of daily hydrologic (precipitation and streamflow) data.

Regional Forecast Data Set

M. Kanamitsu (SIO), D. Cayan (SIO)

Four initial years of a 50-year downscaling effort of a high resolution regional reanalysis has been completed. Analysis of this data (presented in June 2004 at the First California Climate Change Conference) reveal several interesting diurnal and seasonal patterns that define unique circulation patterns. Comparison of these initial results with station data has begun.

Observations in California

D. Cayan (SIO), M. Dettinger (USGS), K. Redmond (WRCC), H. Diaz (CDC), C. Millar (USGS)

Efforts continue to move forward in building partnerships, users and capacity for better observational resources. One effort has been CIRCMONT, a high elevation monitoring and research development that spans the western United States.

High Resolution Spatial Mapping

K. Redmond (WRCC), A. Gershunov (SIO)

Working with CLIMAS, collaborators continue to address the needs for better spatial mapping including user interfaces, accessibility and education.

Evaluation of WRCC Data Requests

K. Redmond (WRCC), D. Cayan (SIO)

A format is under development for surveying WRCC data users (with California data requests) to learn what information is being sought and how the information could be improved.

Research Accomplishments

CAP is a highly collaborative program with participants from throughout SIO and other state agencies/institutions. Research results are presented herein by association to the contributor.

Anthony Westerling

Western North American Fire Histories: integrated documentary records of western North American state, federal, and Canadian large fires into a single large fire database for fire-climate research.

Large montane and subalpine forest fires: analysis of climate driven increase in incidence of large forest fires in western US.

Wildfire forecasting: provide seasonal area burned forecasts to federal fire managers and working with end users to develop earlier forecast information for budget planning.

Alexander Gershunov

Work on extreme daily precipitation events in Climate has yielded a rigorous probabilistic model and a deeper understanding of what climatic and geographical factors control the volatility of precipitation (Panorska, Gershunov and Kozubowski 2005). This stochastic framework is being applied to study Californian precipitation extremes.

We are also studying the summertime variability and seasonal predictability of daily temperature extremes in the California and the Western United States, due to both natural and anthropogenic factors. Alfaro, et al. (2004, 2005) quantified interannual variability and seasonal predictability,

Hugo Hidalgo

Described the variability of reference evapotranspiration (ETo) from California Irrigation Management Information System (CIMIS).

Studied patterns of low-frequency variations on western U.S. Palmer Drought Severity Index (PDSI) using gridded tree-ring reconstructions.

Identified, from a surface energy/hydrology model simulation, differences between seasonal hydrologic structure in regions that are water limited and not water limited in the western U.S., particularly with respect to their response to warming.

Tim Brown

CEFA provides operational fire weather products to the California and Nevada Smoke and Air Committee (CANSAC). To assess the extent that CANSAC is a partnership given synergy characteristics and determinants, and how well the CANSAC structure is functioning in terms of a sustainable partnership, a formal survey was conducted of the Board of Directors, Operational Applications Group and the Technical Advisory Group. Questions covered six general categories: partnership structure, organizational design, availability of resources, CANSAC management, CANSAC leadership, and CANSAC progress. On a scale of 1 (strongly disagree) to 5 (strongly agree), the overall score was 4, indicating that after only one year of operation CANSAC has formed a strong partnership. A journal paper on scientific partnerships and these results is being prepared jointly between CAP/CEFA and CLIMAS.

Mike Dettinger

Ensemble analysis of 86 IPCC IV projections of 21st Century climate changes over California illustrate that (a) temperature changes in the most recent projections are quite generally about 0.5 to 1.0 C cooler than in previous SRES (IPCC III assessments), even when projections from the same modeling centers and emissions scenarios are compared; however otherwise the amount of scatter and the general temperature tendencies in current projections have changed relatively little overall; and (b) the strong tendency for projections of 21st Century precipitation over California (and indeed over the whole of the mid-latitude US) to differ relatively little from 20th Century simulations is even stronger in the IPCC IV ensemble than in the smaller IPCC III ensembles. These results will help to put the emergence of yet another (larger) set of climate-change projections into context for California policy makers, resource managers, and earth scientists.

Trends have been detected in historical records of rain vs. snow contributions to precipitation across western US over the past 50 years, such that a smaller fraction of western precipitation has fallen as snow and more as rain in recent decades (in response to warmer temperatures), Paper in review. Another unexpected trend in the

temperatures at which snow actually falls has been detected, reflecting differences in the warming rates near the surface (where the long-term temperatures have usually been measured) and aloft (where the partitioning between rain and snow occurs).

Long-term historical analyses of conditions that dictate orographic patterns of precipitation and of pineapple-express storms in California have helped to identify the interannual conditions that are associated with strongly orographic precipitation and the occurrence of pineapple-express storms, and have helped to map the areas in California that respond similarly (in these regards) to various phases of ENSO and PDO. Two proceedings paper describing preliminary results published; research continues.

Randy Hanson

Compiled and conducted preliminary analysis of ground-water levels, streamflow and diversions, and precipitation for Central Valley. This will be used in preparation for using the Farm Package with GCM precipitation for simulating ground-water flow.

Kelly Redmond

Developed a western climate anomaly map interface has been developed, for all western states and for the West as a whole, to track climate with daily updates. Awaiting higher end computer to do all states, but for now California, Arizona and West maps are re-computed every day, approximately 2000 maps. www.wrcc.dri.edu/anom

Downloaded California Cooperative Snow Survey data, a very laborious process, and put into WRCC database. Initial evaluation is under way. Spring 2005. These can be viewed on the Calclim web pages at www.calclim.dri.edu

Steven Taylor

Gathered and begun to analyze surface wind data (buoy and satellite observations; NCEP Reanalysis and other model fields). Described the spatial and temporal variability of northwesterly surface wind along the California coast, the dominant climatic feature of coastal California in spring and summer. Began analysis of large-scale atmospheric circulation associated with northwesterly surface wind along the California coasts, and to understand seasonal changes in structure.

Konstantine Georgakakos

Towards improved Northern California water resources management, developed a simplified surface air temperature model for the Sacramento River drainage to be used to downscale atmospheric model information. Tests with observed data and comparison with MM5 runs indicate considerable skill and significant computer savings.

Continued work to develop and assess climate and hydrology ensemble prediction and reservoir management model system for northern and central California water resource management.

Dan Cayan

Conducted research to describe structure and variability of Santa Ana wind events, which greatly increase potential for extreme wildfire events in Southern California.

Assembled observations and global model simulation datasets to explore possible regional climate changes in California, with particular attention to impacts on hydrologic variability.

Continued investigation of effects of climate variability on culex Tarsalis and other species involved in transmission of encephalitis and West Nile virus.
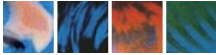
Impact of Climate Variability on Sea Level Accelerations

Peter D. Bromirski, Arthur J. Miller and Reinhard E. Flick (SIO)

NOAA Technical Contact: James Todd (OGP)
Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance
Society's Ability to Plan and Respond

Research Objectives and Specific Plans to Achieve Them

Determine if long period (interdecadal) changes in relative sea level height (SLH) observed in tide gauge records along the U.S. West Coast can be modeled by large scale changes in North Pacific Ocean circulation resulting from altered atmospheric forcing (wind stresses and surface heat fluxes). Determine the importance of coastally-trapped Kelvin-type waves on monthly to annual SLH variability observed in tide gauge data along the West Coast by comparison of tide gauge data with modeled SLH.

Approach, Evaluation and Methodology

Non-tide residuals (NTR) for nine tide gauge stations from San Diego, CA to Ketchikan, AK provided an estimate of local meteorologically-forced changes in sea level height (SLH). NTR include SLH fluctuations due to barometric pressure changes and local winds as well as other local-to-regional monthly-scale forcings. Removing the NTR from the raw tide gauge data gives meteorologically-corrected data sets to be compared with modeled SLH changes. The broad-scale spatial and temporal SLH variability can be estimated by EOF and principal component analysis of monthly meteorologically-corrected tide gauge data anomalies to be compared with modeled SLH anomalies obtained from a primitive equation general circulation model.

Research Accomplishments

Simulations using a primitive equation model (OPYC) indicate that a significant portion of observed interdecadal changes in relative sea level (RSL) along the West Coast can be explained by large scale changes in North Pacific Ocean circulation driven by atmospheric forcing (wind stresses and surface heat fluxes). Long-term trends in sea level are also partially explained by this mechanism. Model RSL anomalies are driven primarily by wind stress forcing, suggesting a close relationship with thermocline variation in coastal waters. The model coastal RSL anomalies are correlated with other coastal RSL anomalies (both modeled and observed) and tend to be anti-correlated with open-ocean offshore model RSL anomalies, reminiscent of the Pacific Decadal Oscillation (PDO) pattern. However, the model RSL anomalies are two to three times smaller than the observed RSL anomalies. The model coastal resolution appears to be inadequate to link broad-scale patterns to local response. The encouraging results from these simulations motivate a more detailed study of the effects of coastal topography on the model RSL, including the effects of poleward-propagating coastally trapped disturbances, better-resolved shelf-slope topography, and improved estimates of atmospheric forcing.

This study attempted to determine the relative importance of wind stress versus surface heat flux anomalies in driving interdecadal RSL fluctuations along the U.S. West Coast. The ocean model with heat flux anomalies alone was forced and compared to the run forced by both wind stress and heat flux anomalies. The fluctuations of RSL from the heat-flux-only forced run are much smaller (by a factor of 5) than those of the complete-forced run. This indicates that the wind stress forcing dominates the driving of interdecadal fluctuations in sea level in this region.

The amplitudes of the modeled interdecadal RSL fluctuations using both wind stress and heat-flux forcing are, however, smaller than the observations by a factor of 3. Yet these modeled fluctuations correlate rather well with the observed, suggesting that estimates of the forcing magnitudes may be too small, that local topographic effects may be causing an enhancement to the observed response, or that a remotely forced response along the shelf-slope system may be important. The latter point was evident in that poleward-propagating coastal waves were not evident in animations of our coarse-model hindcasts with OPYC (suggesting the need for a

higher resolution model) while they are clearly seen in both TOPEX sea level (Strub and James, 2002) and in an ECCO data assimilation hindcast (Stammer et al., 2003).

This large-scale linkage was addressed in two ways. First, EOFs of RSL were computed from the tide gauges alone to determine alongshore coherency among the gauges. The coastal stations are all highly correlated for observed EOF mode 1, but uncorrelated to Honolulu sea level. Mode 2 reveals an out of phase relationship between tide gauges north and south of 40N (similar to the pattern observed by Chelton and Davis, 1982, and by Bromirski et al. (2005a) in an analysis wave spectral energy variability using buoy data from the northeast Pacific), again yielding no strong correlation with Honolulu. The third EOF amounts to a mode that is dominated by Honolulu sea level with no significant response at the eastern boundary. (The model EOFs compare remarkably well with the observed, except that modes 2 and 3 exchange order.) If there is a large-scale mode of open-ocean sea level variability, these results suggest that it does not extend to Hawaii or that it has a node at Hawaii. Firing et al. (2005), in contrast, show that Hawaii is highly correlated to open ocean sea level (dynamic height) determined by hydrography.

North Pacific Climate Variability and Steller Sea Lion Ecology: Retrospective and Modeling Analysis

Arthur J. Miller and Bruce Cornuelle (SIO)

NOAA Technical Contact: John Calder (OAR)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management

Research Objectives and Specific Plans to Achieve Them

Around 1976-1977, the Steller Sea Lions (SSL) in the western Aleutian Islands started a decades long decline in population size. This decline occurred at the same time that populations in the eastern Gulf of Alaska (GOA) were stable or slightly increasing in abundance. Many reasons have been proposed for this pattern of decline/stability in the SSL populations including predation, pollution, and loss or change in traditional prey populations. Because the decline was observed to begin after a major shift in the north Pacific climate regime in late 1976, climate change has also been suggested as a cause. Our research explores the possibility of a climate origin to the SSL population trends centered around the 1976 shift and has been split between the PI's, and collaborators, to examine long-term variability in climate and oceanography (NOAA), examine an approximate 40 year period which includes the shift (NOAA, NCAR), and to perform model based experiments on the periods before and after the shift (SIO).

Approach, Evaluation and Methodology

Schwing, Bograd, and Mendelssohn (NOAA) performed a retrospective analysis of North Pacific Ocean temperature and climate data to establish long-term trends in SST patterns. Using state-space models, they derived nonparametric SST trends from 26 locations in and around the Gulf of Alaska for the period 1950-97. Results indicate significant spatial heterogeneity in SST across the region indicated by five distinct regions defining robust zonal and meridional asymmetry. The meridional differences reflect the relative impact of El Nino events, while the zonal differences reflect variations in the timing and amplitude of a region-wide post-1970 warming trend. The warming trends are of sufficient magnitude and duration to potentially foster changes in lower trophic productivity and structure, which could lead to a broader ecosystem reorganization. Regional differences in SSL population trends may have resulted from these spatially heterogeneous upper-ocean responses to large-scale climate variability.

Alexander & Capotondi (NOAA), and Deser (NCAR) used the output from an ocean general circulation model (OGCM) driven by observed surface forcing to examine the upper ocean changes that took place in the Gulf of Alaska over the period 1958-1997. Their study resulted in an increased understanding of the pycnocline variability in the Gulf of Alaska which, in turn, allowed the SIO team to better interpret their modeling results.

Miller (SIO), Cornuelle (SIO), Musgrave (UAF), and Hedstrom (UAF) used implementations of the Regional Ocean Modeling System (ROMS) to examine circulation in the GOA. The SIO team modeled the circulation in the GOA for the period 6 years before and after the 1976-77 climate regime shift. Our expectations, if the decline in SSL is climatic in origin, are for changes in the circulation patterns of the GOA which negatively impact the SSL's food chain along the western Aleutians while not affecting the food chains in the eastern GOA. What they found corroborates this view. Focusing on mesoscale eddies, a possible mechanism for transporting nutrient-rich open-ocean waters to productive shelf regions, they found an east-west spatial asymmetry in changes in the eddy fields associated with the Alaskan Stream and Alaskan Current. After the regime shift, the velocity of the Alaskan Stream along the Aleutians changed dramatically while the Alaskan Current in the eastern Gulf remained relatively unchanged. This climate-driven mechanism, which has a characteristic east-west spatial asymmetry, may potentially help to explain changes in forage fish quality in diet diversity of Steller sea lions whose populations have declined precipitously since the mid-1970's in the western Gulf while remaining stable in the eastern Gulf.

Research Accomplishments

A distinct change in the ocean circulation of the Gulf of Alaska after the 1976-77 climate shift was observed in our model runs. After the Aleutian Low strengthens, mean velocities of the Alaskan Stream increase northeast of Kodiak Island and decrease southwest of it. Mesoscale eddy variance likewise increases to the northeast of Kodiak and weakens to the southwest. Mean and eddy flows in the eastern Gulf remain unchanged after the shift. Since mesoscale eddies provide a possible mechanism for transporting nutrient-rich open-ocean waters to the productive shelf region, the flow of energy through the food web may have been altered by this physical oceanographic change. This mechanism may explain the changes in forage fish quality in diet diversity of Steller sea lions whose populations have declined precipitously since the mid-1970's in the western Gulf while remaining stable in the eastern Gulf.

In addition, we use the output from an ocean general circulation model (OGCM) driven by observed surface forcing to examine the upper ocean changes that took place in the Gulf of Alaska over the period 1958-1997, including the 1976-77 climate regime shift. The pycnocline deepened after the mid-seventies in a broad band along the coast, and shoaled in the central part of the Gulf of Alaska. The changes in pycnocline depth diagnosed from the model are in agreement with the pycnocline depth changes observed at two ocean stations in different areas of the Gulf of Alaska. Using a simple Ekman pumping model with linear damping we show that a large fraction of pycnocline variability in the OGCM can be explained by local Ekman pumping. The fit of the simple model to the OGCM is maximized in the central part of the Gulf of Alaska, where the pycnocline variability produced by the simple model can account for ~70-90% of the pycnocline depth variance in the OGCM. The agreement between simple model and OGCM deteriorates in a large band along the coast, where the propagation of disturbances within the pycnocline appears to play an important role in pycnocline variability. Propagation of pycnocline depth anomalies is especially relevant in the western part of the Gulf of Alaska, where local Ekman pumping changes would lead to pycnocline variations of the opposite sign than those in the OGCM. The inclusion of a propagation term in the simple Ekman pumping model considerably improves the agreement with the OGCM along the coast.

Conclusions and Recommendations: In broad terms, the suite of studies that have been undertaken to investigate the temporal and spatial differences in ocean climate in the North Pacific have identified ocean climate patterns that are consistent with the patterns of sea lion distributions, population trends, numbers and diets. The oceanic response to climate forcing after 1976-77 has an east-west asymmetry, with stronger changes occurring in the western Gulf of Alaska. The geographic clustering of sea lion diets and population trajectories, and their correspondence with key biogeographic and oceanographic features of the Gulf of Alaska and Aleutian Islands add credence to the view that there is a linkage between Steller sea lions and the physical environment. However, additional studies will be required on finer spatial scales to draw firmer conclusions, particularly in regions closer to shore where sea lions spend more time foraging.
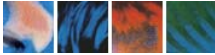
Preparation and Analysis of an Extensive Historic Dataset of Ocean CO₂ Partial Pressure and Related Measurements

Charles D. Keeling (SIO)

NOAA Technical Contact: Lisa Dilling (OGP)
Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Research Objectives and Specific Plans to Achieve Them

Prepare an analysis of an historic oceanic CO2 partial pressure (pCO2) dataset.

Approach, Evaluation and Methodology

To update the methodology for calculating pCO2 from chemical properties of seawater samples, collected at sea and chemically analyzed in our shore laboratory. This revised methodology allows us more reliably to link historic from underway measurements at sea from 1957 to 1967 to our subsequent shore-based measurements of chemical properties.

Research Accomplishments

No accomplishments can be reported at this time due to the passing of Dr. Charles D. Keeling this past year. Currently, a search is underway within the SIO community to appoint a new principal investigator qualified to continue the work of this project. Dr. Keeling is recognized as a pioneer in climate sciences and a leading authority on atmospheric greenhouse gas accumulation. His experience, talent, and presence at SIO, an Institution with which he has been affiliated since 1956, will be greatly missed.
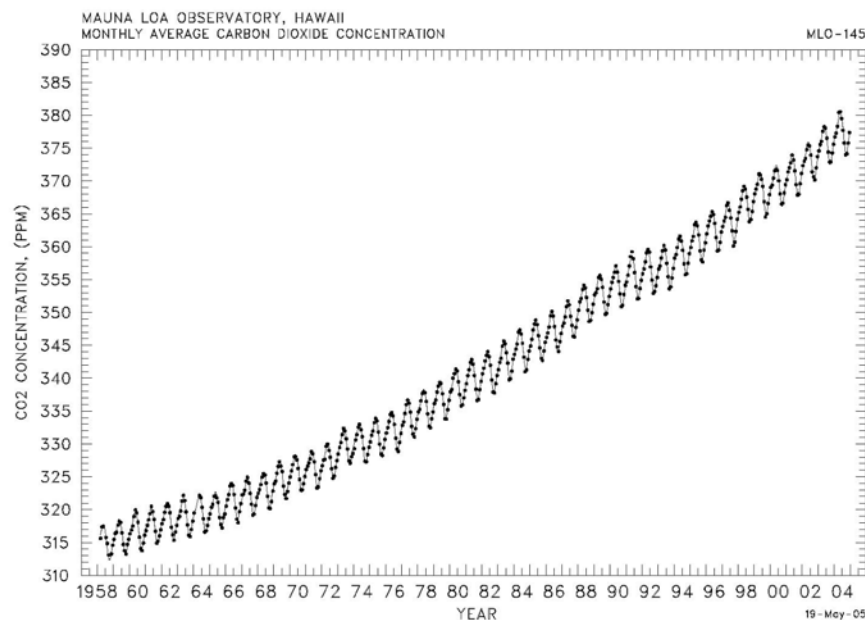
Image Courtesy of Scripps Institution of Oceanography/UCSD © 2005
Fig. 1 The Keeling curve, representing atmospheric CO₂ data at Mauna Loa, Hawaii, through 2004.

CO2/CLIVAR Repeat Hydrography Program

Andrew G. Dickson (SIO)

NOAA Technical Contact: Sidney Thurston (OGP)
Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Research Objectives and Specific Plans to Achieve Them

A Science Team is funded and coordinated by this project (Project Director, Dr. R. Feely, NOAA/PMEL) to collaborate and discuss data archival for the CO2/CLIVAR Repeat Hydrography Program.

Approach, Evaluation and Methodology

Team members met in Miami, Florida on October 5, 2004. Along with data archival techniques for this program, we discussed strategies for the design of new analytical equipment for the later stages of this program.

Research Accomplishments

Since the meeting in the fall of 2004, the research group tasked to this project under the supervision of A. Dickson has made progress to ensure that data from this group is in the appropriate form for public release. The next meeting is planned for the Summer of 2005.

Oceanic Measurements of Total Alkalinity

Andrew G. Dickson (SIO)

NOAA Technical Contact: Kathy Tedesco (OGP)
Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Research Objectives and Specific Plans to Achieve Them

Project Goals/Thrust Areas:
1.	Improvement of the measurement technique for alkalinity by developing a spectrophotometric-based end-point detection technique than can be used both at sea and for shore-based measurements.
2.	The steady accumulation of a high-quality global data set for the distribution of total alkalinity in the surface waters of the global oceans. This will be achieved out by shore-based laboratory measurements of alkalinity on samples collected on a wide variety of international oceanographic cruises.

Approach, Evaluation and Methodology

High quality surface alkalinity data is an integral part of current oceanic carbon cycle science. In particular, it is an essential part of the current method used for the estimation of anthropogenic CO2 in the ocean. Here, it is used in two contexts: it is used as a reference level for inferring changes in alkalinity since a water parcel left the surface, it is also used as the basis for estimating the preindustrial total CO2 content of a parcel of ocean water by calculating this value from the surface alkalinity and a p(CO2) value of 280 µatm. The uncertainty of our present data set for alkalinity compromises the sensitivity of these calculations.

Research Accomplishments

1. Alkalinity system development
Uncertainty analysis
In summer 2004, I had a summer internship student, an undergraduate from UCLA: Mr. Andrew McDonnell, who worked on developing a series of Matlab scripts for the simulation of alkalinity titrations. Once these had been developed and tested, Mr. McDonnell used his programs to simulate the effects of errors and experimental uncertainties on the measurement of alkalinity so as to prepare a complete uncertainty budget for this important technique. The most striking finding was that the open-cell technique for alkalinity – as used in my laboratory – is significantly more sensitive to electrode problems than is the older closed-cell technique. This fits with our empirical observations that this was our most significant problem. (Note: the open-cell technique is superior in every other way to the closed-cell technique.) Mr. McDonnell and I have been in contact since then, refining some of his conclusions and I am presently preparing a manuscript for publication based upon his work.

Development of control software for alkalinity titrations
The software that controls our alkalinity analysis was written about 9 years ago, and runs on elderly Macintosh computers. This software has been given to the PMEL group who have modified it to use with modern computers, however before we could significantly improve our method, it seemed appropriate to redesign, rewrite, and improve, this software. The new design will allow a spectrophotometric titration approach to be incorporated relatively straightforwardly. I have thus been rewriting the LabVIEW code from scratch (using a modern PC laptop computer and an external interface from National Instruments). The resulting code, which is almost ready for more extensive testing is much clearer than the original program, and should ultimately be code that could be shared more widely.

Development of a spectrophotometric procedure for the measurement of alkalinity
As I do not have anyone presently working in my laboratory with the necessary background in equilibrium computations, I have been doing this work myself. Thus far, I have developed and tested code to simulate such a spectrophotometric titration and to process the data – allowing for all the various equilibria involved. I have now entered on the next phase, which involves simulating the likely uncertainties: in temperature measurements, spectral information, and – crucially – in the knowledge of the pK and extinction coefficients of the dye. Once I know how well these parameters need to be controlled, it will be practical to assemble and test a prototype system. I expect to be able to do that this summer.

2. Collection and measurement of alkalinity samples
During the last year we have managed to collect a wide variety of surface samples from around the world, among them:
• From the United Kingdom's Atlantic Meridional Transect (from Plymouth, UK to the Falkland Islands) providing data the length of the Atlantic.
• From the Good Hope cruise conducted by European scientists in the South Atlantic.
• From a buoy turn-round cruise conducted off the coast of New Zealand.
• From the NOAA buoy ship, Ka'imimoana in the equatorial Pacific. We are also measuring total dissolved inorganic carbon on these samples as well (this work is being done in collaboration with Dick Feely at PMEL).
• From a cruise in the N. Pacific conducted by scientists from the University of Hawaii (this work is being done in collaboration with Dick Feely at PMEL).
Thus far, we have analyzed about half of the samples collected. The reason for this backlog was because we did not have a complete spare alkalinity system for use in the laboratory and thus when we were involved in Repeat Hydrography cruises, our system was unavailable in the lab. It is now back home again, and we have once more started on analyzing samples. Furthermore, we now have all the components for an additional system in hand, and once our new software is tested will assemble a system that will be used for the remainder of this project.

Potential Application of Recent Collaborative Research Results to Operational Activities at the National Weather Service, Alaska Region

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Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
NOAA Goal 3: Serve Society's Needs for Weather and Water Information

Research Objectives and Specific Plans to Achieve Them

This study, done at the request of the National Weather Service (NWS) Alaska Region, synthesized the research results from the twelve (12) most recent collaborative research efforts between Drs. Gary Hufford (NWS) and James Simpson (SIO) into a set of recommendations for potential improvement in Alaska-specific operational forecasting methods. Drs. Hufford and Simpson have worked jointly to prepare a concise set of specific recommendations and the basis for these recommendations.

Approach, Evaluation and Methodology

A combination of satellite-based retrievals of application-specific analyses products, atmospheric advective / diffusion modeling and statistical analyses of large in situ data sets was used to perform the analyses described in the cooperative research between NWS Alaska Region (Dr. Gary Hufford) and UC San Diego / Scripps Institution of Oceanography (Dr. James J. Simpson). Where appropriate, mathematical methods of data fusion were used to blend results from the three basis types of analyses / data types. Forecasting needs for a specific application were identified jointly by scientists at UC San Diego / Scripps Institution of Oceanography and the operational meteorological agencies (U.S. National Weather Service, Canadian Meteorological Center). Results were compared with operational needs to determine possible failure nodes of an operational analysis and to make specific recommendations for improvement. Project efforts concentrated on three broad areas:

• Aviation hazards to both commercial and general aviation of airborne volcanic ash
• Alaskan climate
• Snow / river ice hydrology and its relation to more accurate streamflow modeling, water resource allocations and flood mitigation

Research Accomplishments

Air-Borne Volcanic Ash
Airborne volcanic ash is a major risk to both civilian and military aviation as well as a potential health hazard for the elderly and those afflicted with respiratory disease. A combination of satellite-based retrievals of airborne volcanic ash, atmospheric advective / diffusion modeling and statistical analyses of large in situ data sets was used to study 9 volcanic eruptions around the world and the ability of NOAA's operational algorithms to accurately detect volcanic ash from these eruptions in the atmosphere. The study showed that seasonal variability in global integrated atmospheric water vapor and the presence of ice in the atmosphere, coupled with the geographical distribution of currently active volcanoes, constitutes a significant and ongoing hazard to both global aviation and public health. Based on this study the Alaskan Regional Weather Service has improved its detection of airborne volcanic ash as well as its operational procedure to alert the aviation and public health communities to its presence in the atmosphere. Moreover, NOAA's Forecaster System Laboratory in Boulder, Colorado currently is implementing a new Volcanic Ash Detection Tool (VACT) to further improve NOAA's capabilities in this important area based on the analyses and operational lessons learned from this study.

Alaskan Climate
As part of NOAA's new Climate Reference Network, the need arose to determine the optimal sites for new and improved climate sensors in Alaska. Optimal site selection is important for at least three separate reasons: 1) to cover regions of Alaska not currently observed (e.g., high mountain ranges like the Books Range); 2) to locate sensors in regions of largest climate uncertainly; and 3) to optimize the design with the careful attention to cost as limited funds are available for the Alaskan component of the Climate Reference Network. Alaska is particularly important for monitoring global warming processes because Alaska is viewed as the "canary in the bird cage" indicator for global change processes. A climate analysis, which compared modeled surface temperatures and precipitations from two different models (the ANUSPLIN and the PRISM models), was conducted to determine the regions in Alaska with maximum and minimum uncertainty in our knowledge of space / time variation in long-term surface temperature and precipitation (Simpson et al. 2005). Specific recommendations for the roll out of NOAA's Climate Reference Network are also given in this paper. Finally, this comparison study provides information useful to a wide constituency (Federal (National Park Service, Bureau of Land Management), State (Alaskan Department of Natural Resources) and Industry (oil and gas exploration, commercial timber and fishing)) in their selection of the best appropriate baseline maps of Alaskan surface temperature and precipitation for use in their applications.

Improved Hydrologic Stream Flow Prediction
Stream flow river forecasting is especially difficult in Alaska for a variety of complex reasons (e.g., spring breakup can be sudden and swift; extratropical storms can produce sudden, intense and extensive rainfall). Based on a recent work (Simpson et al. 2004), several improvements in operational stream flow forecasting are now possible. The River Forecast Center (RFC) of the Alaskan Region hopes to incorporate some of these concepts into its operational stream flow forecasts. A global climatological analysis of atmospheric water vapor, based on a combined in situ and remote sensing data set, also was performed (Simpson et al. 2001); this study provided information useful for both improved airborne volcanic ash detection and hydrologic stream flow prediction.
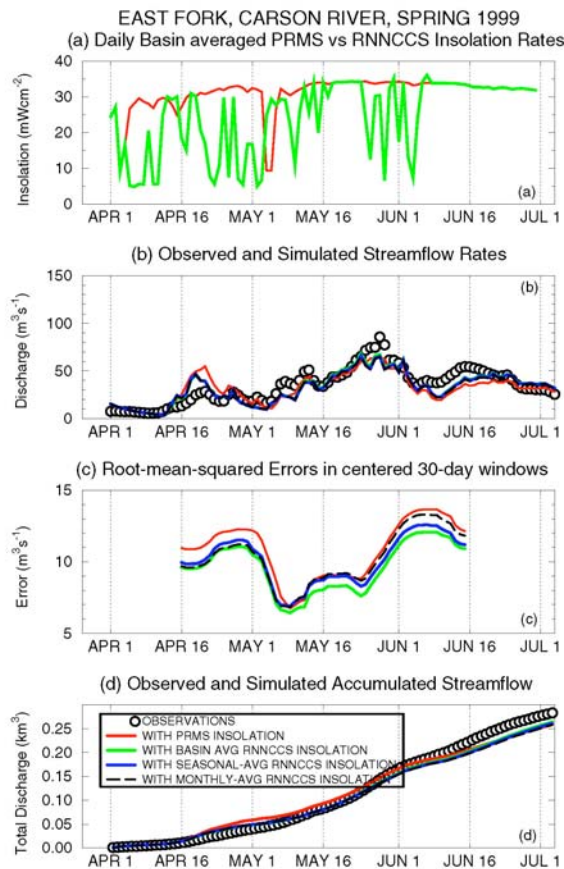
Fig. 1 Comparisons of (a) daily PRMS estimated and RNNCCS insolation estimates, (b) observed and simulated stream flows, and (c) root-mean-squared errors, for east fork of the Carson River basin, snowmelt season 1999, and (d) cumulative volume flow for the different insolation estimates as indicated. PRMS is a widely used operational stream flow model. RNNCCS refers to the new satellite retrieval process developed by Simpson and McIntire (2001c) for aerial extent of snow and cloud cover for insolation (from Simpson et al., 2004a).

California Cooperative Oceanic Fisheries Investigations Time-Series and the Development of PaCOOS

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Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management

Research Objectives and Specific Plans to Achieve Them

California Cooperative Oceanic Fisheries Investigations (CalCOFI) is a partnership among the National Marine Fisheries Service, Scripps Institution of Oceanography, and Calif. Department of Fish and Game. The goal is to understand the oceanography and ecology of the California Current system and to provide the scientific basis for wise use of its biological resources. Initiated in 1949, it is now the longest ocean observing program in North America. JIMO funding provides for the continuation of the CalCOFI observations while NOAA develops the Pacific Coast Ocean Observing System (PaCOOS). PaCOOS will ultimately link ocean observing programs along the entire west coast of the United States, and will strengthen collaborations with similar programs in Mexico (IMECOCAL) and Canada. CalCOFI will be a key component of PaCOOS.

Approach, Evaluation and Methodology

During the past year we have continued the time-series with four cruises. To maintain the continuity of the data set, we depend heavily upon past techniques and sampling design. Technical changes are made only after careful cross-calibration. This past year we continued the development of an optical procedure for estimating primary production that will ultimately supplement and then perhaps replace the standard 14C procedure. (This work is funded through SCCOOS). We also seek to strengthen traditional measurements with the addition of new data or measurements on different time/space scales (e.g. Fig. 1). These are also funded by ancillary projects.

Research Accomplishments

GOAL 1:

Most oceanographic conditions during the past year were atypically "normal" in the CalCOFI region (Goericke et al. in press). However, silicate concentrations in the mixed layer since 2003 have been the lowest on record. This indicates an increased frequency of silicate limitation on diatom growth (Goericke et al, in prep; Fig. 2). A reduction in diatom biomass could have direct implication for reproductive success of higher trophic levels, including birds and fish, and we continue to follow the development and ecological manifestations of this anomaly.

During the past year, we have continued to expand the scope of CalCOFI observations and the strength of analyses with the continuation and addition of collaborative programs. Programs established and on-going at the start of this review period include:

1. Investigaciones Mexicanas de la Corriente de California. Established in 1997 and funded by Mexican agencies, IMECOCAL continues the quarterly CalCOFI pattern from the Calif-Mexican border along the coast of Baja.

2. Pt. Reyes Bird Observatory. Since 1987 personnel from PRBO have made quantitative surveys of pelagic birds and whales on every CalCOFI survey.

3. The quarterly cruises serve as research platforms for graduate student research. Two ongoing projects are a study of dissolved organic carbon cycling and a study of the utilization of iron and nitrate by phytoplankton in the Southern California bight.

Programs essentially new to this review period include:

1. California Current Ecosystem/Long Term Ecological Research Program. Funded by NSF in 5-year, renewable increments, this program adds several new measurements to the CalCOFI time-series and allows focused research into ecological responses to physical and climate change. There is a significant bio/physical modeling component The strength of the CalCOFI/LTER partnership is demonstrated by a recent paper in Nature (Hsieh et al. 2005), which quantitatively demonstrates non-linearities in biological time-series. The analysis was funded by LTER, and was based upon CalCOFI data. The conclusions have important implications for fisheries management. The LTER program includes an Education and Outreach Component that applies equally to CalCOFI.

2. Funding from the Southern California Coastal Ocean Observing System (SCCOOS) allows CalCOFI to extend surveys toward the coast. When possible, seven stations are occupied in 10 fathoms depth, one at the end of each cardinal line, and one midway between. These stations will provide a bridge between the offshore observations of CalCOFI and the nearshore observations of SCCOOS. SCCOOS is also supporting the development of a bio-optical method for estimating primary productivity.

3. Prof. John Hildebrand of SIO has received 4-year funding from ONR to make quantitative acoustic and visual observations of cetaceans in the CalCOFI region, using moored recorders and visual and acoustic observations from CalCOFI ships. The intent is to relate cetacean location to mesoscale oceanographic features.

4. Recently, a Moore Foundation award was received to enhance the temporal resolution of the quarterly surveys by deploying autonomous ocean gliders along two CalCOFI lines between cruises. A shipboard free-fall Moving Vessel Profiler will provide nearly continuous spatial coverage of the upper ocean between stations. These two instruments will significantly improve our ability to resolve changes in hydrographic structure and plankton communities.

GOAL 2:

In anticipation of the Pacific Coast Ocean Observing System, we have continued to advance our data processing procedures, with the final goal being a nearly autonomous computer-based system that maintains our traditional high standards of data quality. This will make CalCOFI data more quickly available and more easily communicated. All cruises from 2004 are currently available on line (http://www.calcofi.org/newhome/data/data.htm).

A strategic effort in preparation for PaCOOS has been the preparation of a "white paper" that provides a comprehensive review and summary of the vast and disparate data now collected by CalCOFI; it also initiates an information management approach with initial recommendations relating to organization, work-flow, cross-community coordination, as well as database design and development. These will facilitate integration of the CalCOFI data set into the larger PaCOOS system. CalCOFI provides a spectrum of the data management challenges that will need to be addressed by PaCOOS. It is anticipated that defining and resolving these on the CalCOFI scale will inform the development of the more complex federated system. The "white paper" will be distributed to the CalCOFI Committee for comment this summer, and some recommendations are already being implemented.
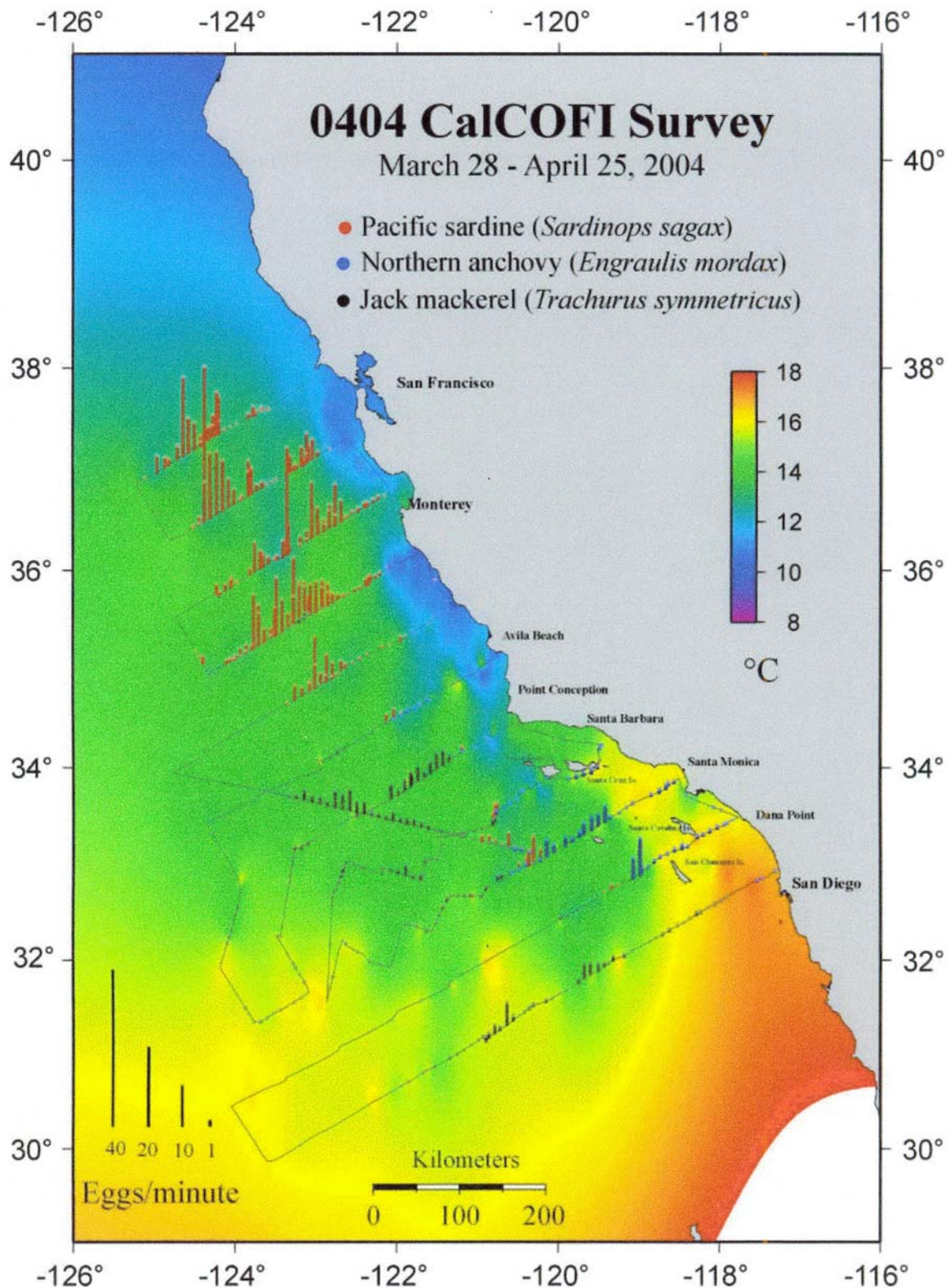
Fig. 1 Occurrence of eggs of Pacific sardine, northern anchovy and jack mackerel sampled with the continuous underway fish egg sampler (CUFES), and sea surface temperature, April 2004. Sardine egg distribution was displaced to the north relative to recent years.
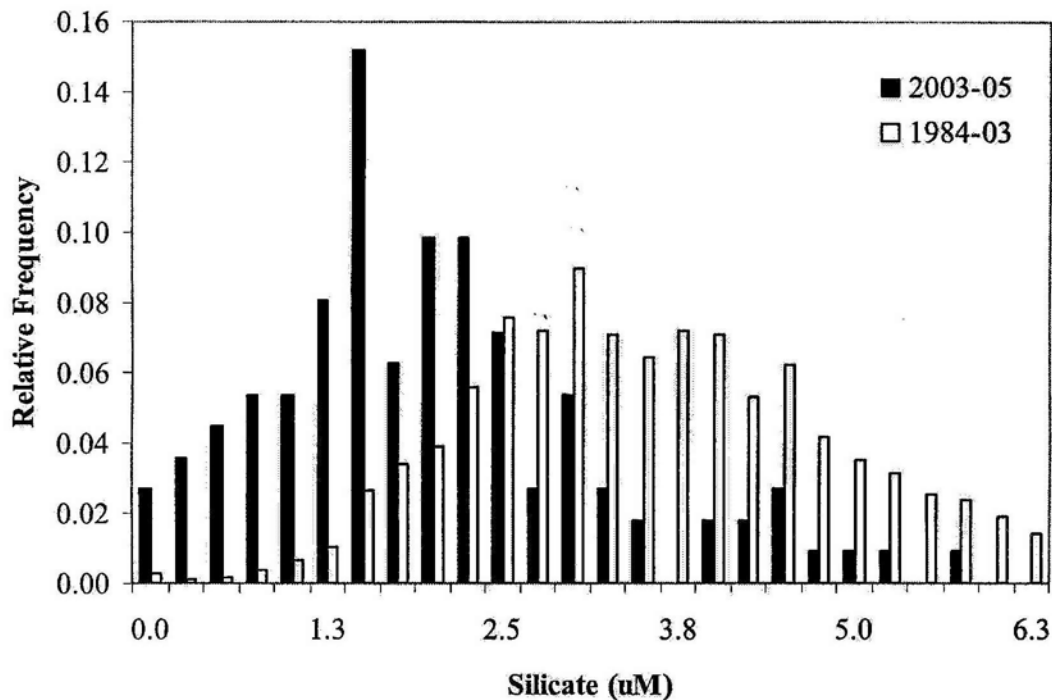
Fig. 2 Normalized frequencies of mixed lay silicate at CalCOFI stations with nitrate concentrations greater than 0.3 µM (from Goericke, et al., 2005 in prep).
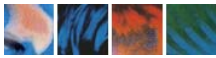
Southern California Coastal Ocean Observing System (SCCOOS)

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NOAA Technical Contact: Geno Olmni (NOS)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
NOAA Goal 3: Serve Society's Needs for Weather and Water Information

Research Objectives and Specific Plans to Achieve Them

State and federal initiatives encourage the establishment of an integrated ocean observation system (IOOS) along the nation's coastlines to assist agencies and resource managers with decision making and planning. The system is envisioned as a network of regional systems, with the Southern California Coastal Ocean Observing System (SCCOOS – www.sccoos.org) serving as the regional network for this area. SCCOOS successfully integrates multidisciplinary coastal observations in the Southern California Bight (SCB) for observing, integrating, predicting and disseminating ocean conditions. In SCCOOS, ocean and coastal observations, data communication, modeling, research and educational programs are ongoing to meet the information needs of data users in the region.

The work described herein illustrates pilot efforts to integrate geology, meteorology, oceanography, ecology, and new science and observing technology toward addressing regional problems concerning erosion, water quality, coastal hazards, and marine life resources. Progress is described here in sections pertaining to these pilot efforts (for example, HF Radar, Autonomous Observations, Nearshore Observations, Marine Life Resources, Modeling, Data Management, Outreach & Education). Each focus area represents the collaborative work of experts from local institutions contributing to the designs and products described below.

Approach, Evaluation and Methodology

• Long Range (4 MHz) HF radar is being tested in the San Diego region out to ranges of 180km. Sites of two systems will be established at San Clemente Island and Point Loma to provide surface current maps north and south of the U.S.-Mexico Border. UCSB, UCLA and SIO are assessing numerous potential HF radar sites in the region for a SCCOOS wide build out, and are working with private, state, and federal land owners (e.g. U.S. Coast Guard, National Parks, State Parks, and city engineers) as part of this process.
• Moorings- Three oceanographic moorings are now deployed in the Southern California Bight for SCCOOS, and are located in Santa Barbara (UCSB), Santa Monica Bay (UCLA), and La Jolla (SIO). The mooring locations were chosen to coincide with interest areas within the Southern California Bight, and contain physical, chemical, and biological sensors.
• Drifters- High resolution drifters provide coastal ocean surface current observations necessary for proper interpretation of the coarser Eulerian HF radar fields. Drifters quantify sub-gridscale energy and measurement biases, and provide necessary data for HF radar installations.
• Gliders- Underwater gliders are deployed to provide repeated monthly observations of water velocity, temperature, salinity, and phytoplankton abundance on across-shelf sections spanning the Southern California Bight, with vertical resolution of a few meters and horizontal resolution of a few kilometers. Data is posted on a web site (http://spray.ucsd.edu), and will be integrated with data from SCCOOS collaborators for use in assimilating models. At SIO, three Spray Underwater Gliders were ordered from the Instrument Development Group of the Scripps Institution of Oceanography and tested with an Acoustic Doppler Profiler. Additional instrumentation of the gliders will allow initial glider deployments to begin in early CY 2006 as proposed. The gliders will be equipped to measure temperature and salinity profiles, depth-averaged velocity by their motion, and profiles of velocity structure with an Acoustic Doppler Profiler.
• Nearshore- Nearshore studies focus on the shoreline and about 2km offshore (roughly 30m water depth), a region that includes the surf zone (where waves actively break) and the transition zone between the surfzone and shelf. Projects exist to network and manage water quality data from regulator and regulated stakeholders (e.g. NPDES permit holders and health agencies), development and testing of transport and dispersion models that are driven by ocean waves, and AUV operations at select sites to resolve space and times scales of variability.
• Marine Life Resources- Additional in-shore stations have been added to the CalCOFI grid to extend their synoptic maps of biological variables to the nearshore. All moorings supported by SCCOOS will include bio-chemical sensors. Chlorophyll and nutrient sampling have begun from piers in the region to gather information regarding harmful algal blooms.
• Modeling- A Regional Ocean Model (ROMS) that assimilates data is operated at JPL, with research conducted on new physics and assimilating techniques at UCLA and SIO. Data intended for assimilation include CalCOFI surveys, altimetric observations of sea level, glider surveys, continuous CODAR surface currents, moorings and REMUS transects. ROMS surface currents will be compared with real wind forcing to those observed in the state-funded CODAR array.
• Remote Sensing- "Non standard," remote sensing data products are in development, and the acquisition and processing of internationally operated satellites are being conducted. Products to communicate remote sensing data to users in a simple manner are also being developed.
• Data Management- Data managers are developing user interfaces for web access, differentiating classes of users as "general public," "engineering view," "scientific community," and "decision makers." Programmer efforts also include synthesizing updates into the SCCOOS website for data products, modeling, and community and classroom activities.
• Outreach- SCCOOS has partnered with the Ocean Institute in Dana Point to develop an eight-week program designed to meet 5th grade Earth Science standards on the water cycle and weather; the program will include new classroom activities, science kits, CD-ROMs, web-based materials, field trips, teacher professional development and will incorporate SCCOOS science and scientists as a link to research being done in the field. Curriculum development for this program will occur over a three-year period, and will include teacher focus groups and training sessions in order to develop a program that effectively helps prepare students for California science standards and rigorous new assessments. The program will be piloted with approximately 500 students in three school districts, and will eventually be disseminated to 16,000 students in Orange County.

Research Accomplishments

•   Development of a web portal for information distribution (www.sccoos.org) that will be built upon to also host a data distribution site for SCCOOS observations. An online site management tool, http://sccoos.org/SoCal, was created for tracking and managing HF radar sites.

•   Mooring data suggest that spring, 2005, was characterized with modest strength of upwelling, but perhaps in response to the exceptional wintertime input of nutrients from runoff, a large and persistent phytoplankton bloom developed. Initial analyses of the phytoplankton community structure show that the bloom and particularly its later phases were dominated by dinoflagellates.

•   Glider experiment analysis shows that the regional ocean model is able to assimilate glider data and accurately describe the large scale (>20 km and > 2 days) part of coastal variability but that the coastal mesoscale variability may have such small scales (10 km, 1.5 days) that subsurface mesoscale features will not be well described except very near the observing assets.

•   Mooring operations are becoming robust, with planned developments for real-time data telemetry.

•   ROMS will soon regularly produce time-dependent, three-dimensional maps of the velocity, ocean/air temperatures, salinity, basic ecosystem state (nutrients, phytoplankton, and zooplankton), and sediment transport.
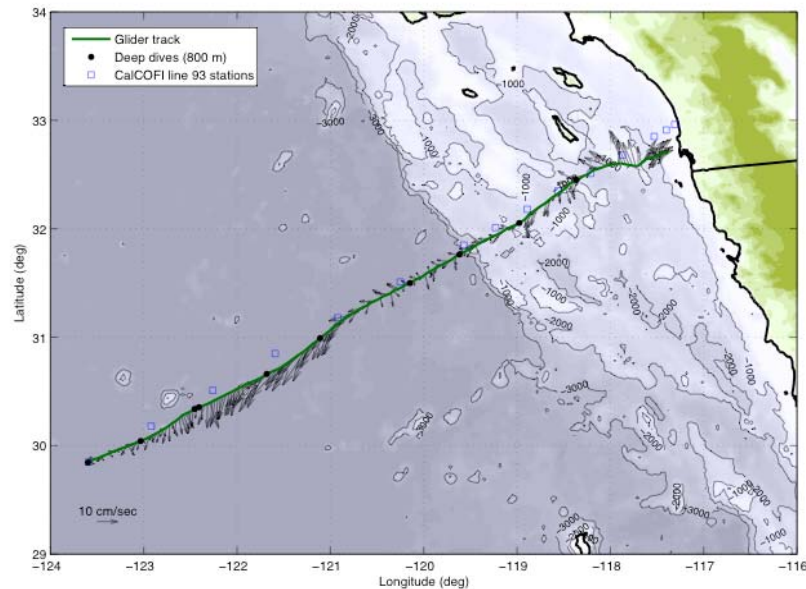
Fig. 1 Glider track along CalCOFI line 93. Vectors are currents averaged over the upper 500 m.
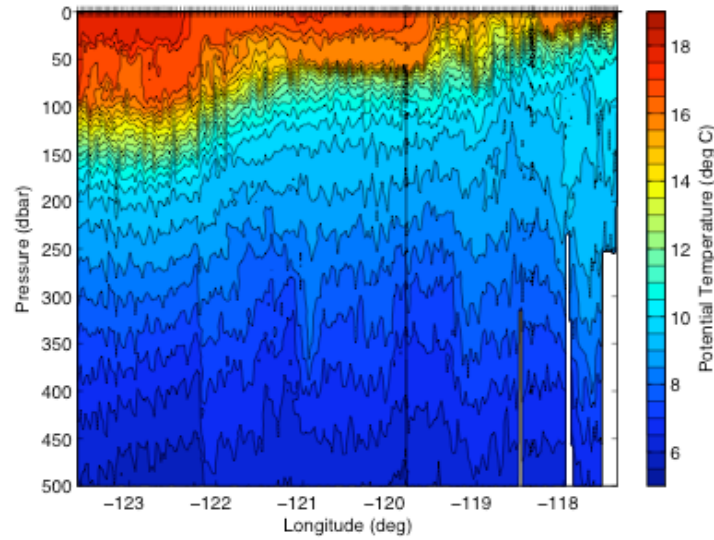
Fig. 2 Section of potential temperature along the track of Fig. 1. Tick marks along the top axis indicate locations of profiles at a resolution of about 3 km.
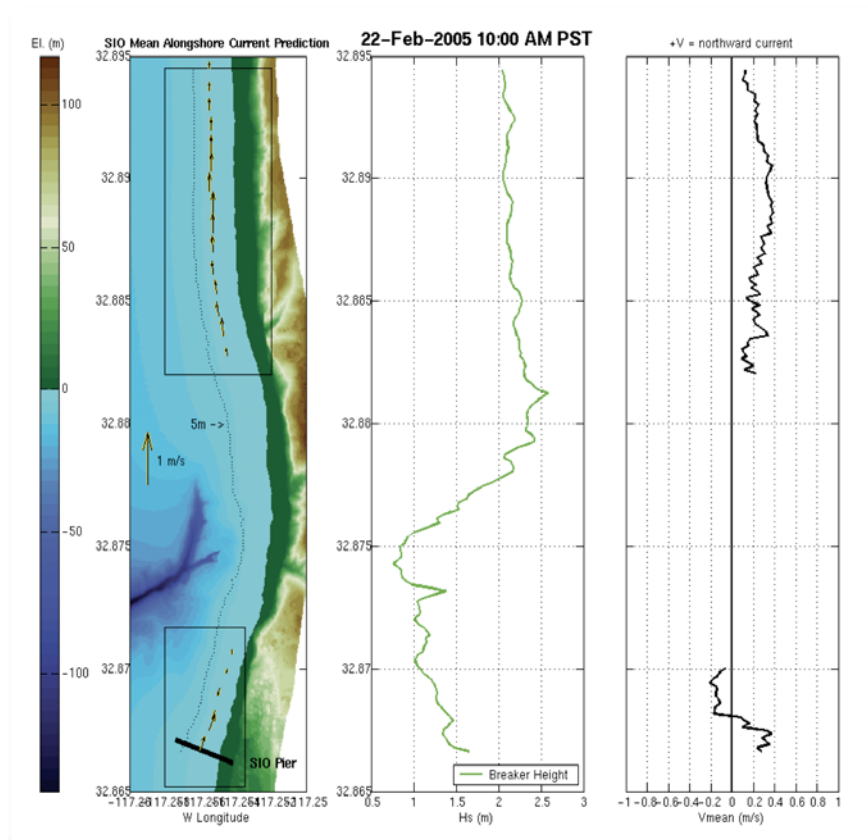
Fig. 3 Along-shore resolution of 200 m of wave height at the seaward edge of the surf zone (middle) and surf zone-averaged along-shore currents (left and right) near Scripps Canyon (San Diego). Similar "nowcasts" will be produced for San Pedro Bay.

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The Center for Stock Assessment Research (CSTAR)

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Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management
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Research Objectives and Specific Plans to Achieve Them

CSTAR aims on training undergraduate, graduate, and post-graduate students in the science associated with the problems of assessing the numerical abundance, spatial distribution, size distribution and reproductive status of commercially important fish species, with the goal of increasing the pool of quantitatively trained scientists.

Approach, Evaluation and Methodology

A focus on training students and post-docs to use mathematical, statistical and computer models to solve important environmental and ecological problems. Work is grounded in data, and seeks to expand the base of basic knowledge that supports rigorous application of science to real-world problems. Furthermore, research on marine fisheries conducted at CSTAR allows testing theoretical problems via natural and human experiments on a scale that is appropriate for understanding the dynamics of ecosystems.

Research Accomplishments

The work at CSTAR is highly collaborative with academia, NMFS, and the California Department of Fish and Game (CDFG) colleagues. Herein we identify the CSTAR member and the project, but in general do not identify collaborators of the students, research assistants or post-docs.

Student Accomplishments

CSTAR Student Chris Wilcox (PhD 2002) moved to a position in the pelagic species division, CSIRO, Hobart Tasmania (moving from a post-doc at the University of Queensland). CSTAR student Holly Kindsvater (BS 2003) started Ph.D. studies in quantitative ecology at the University of Florida and earned a president's fellowship there. CSTAR Post-doc Melissa Snover moved to a position in the stock assessment group, protected species division, Pacific Islands Science Center, Honolulu. CSTAR post-doc Stephan Munch moved to the marine sciences research center, SUNY Stonybrook as assistant professor; 50% of this position is funded by the New York Department of Environment and Conservation, for work on stock assessment. CSTAR post-doc Suzanne Alonzo moved to the department of ecology and evolutionary biology, Yale University, as assistant professor. CSTAR collaborator Meisha Key (CDFG) led the stock assessment of gopher rockfish at the SWFSC SCL. Ms. Key received her training stock assessment methodology at CSTAR, jointly mentored by Dr. Alec MacCall and Prof. Marc Mangel and working with Dr. Alonzo and Ms. Teresa Ish (CSTAR MSc student 2003).

Specific Research Accomplishments

Steve Munch, Thanos Kottas, and Marc Mangel developed Bayesian methods for stock recruitment analysis in the case of a switch in the environmental regime. Suzanne Alonzo, Teresa Ish, Meisha Key, and Alec MacCall completed the first-ever stock assessment of California sheephead. Melissa Snover and George Watters, with professor Marc Mangel, developed methods for predicting life history patterns of coho salmon development and return, in relation to environmental and genetic factors. Mr. Nicholas Wolf evaluated the evidence in support of 10 different hypotheses associated with the decline of the Steller Sea Lion in western Gulf of Alaska and Bering Sea. Andi Stephens and Alec MacCall developed and explored the strengths and weaknesses of a method for

subsetting mixed fisheries data for the determination of appropriate measures of fishing effort in groundfish fisheries and helped colleagues in CDFG deploy these methods. Anand Patil, Phil Levin (NWFSC) and Marc Mangel developed persistence-based methods that can be used to identify essential fish habitat and habitats of particular concern. Anand Patil, Marc Mangel and Alec MacCall developed Bayesian, Bayesian nonparametric, and utility-based approaches for modeling recovery of overfished stocks. EJ Dick developed likelihood-based methods for determining the appropriate characterization of variability in groundfish trawl surveys. Yasmin Lucero explored the implications of recently discovered maternal effects in rockfish on the nature of the stock-recruitment curve. Kate Siegfried and Bruno Sanso developed Bayesian methods for estimation of asymptotic size in the absence of length at age data. Ms. Siegfried applied these methods, and methods previously developed for estimating natural mortality, to California sheephead. Marc Mangel, Xi He and Alec MacCall completed the development of priors for steepness of a stock recruitment relationship based on an evolutionary persistence criterion.
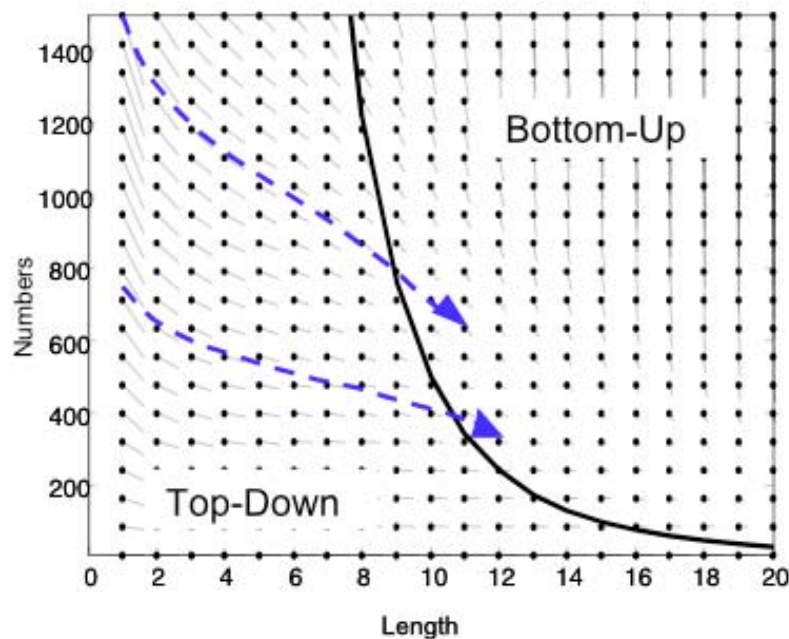
Fig. 1 The theory of Munch et al. (2005) allows one to predict when the recruitment of a population is more regulated by top-down or bottom-up factors, as a function of size of individuals and number of individuals in the cohort. The bold black line indicated those combinations of population number and individual size at which the two factors balance.

Genetic Population Structure of Central California Coastal Salmonid Populations

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NOAA Technical Contact: Churchill Grimes (NMFS)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management

Research Objectives and Specific Plans to Achieve Them

- Determine the population genetic structure of extant runs of coho salmon, chinook salmon and steelhead trout in the Central California Coastal region.
- Identify appropriate broodstock for salmonid recovery efforts.
- Estimate values of population genetic parameters in salmonid populations.
- Evaluate inter-year and inter-basin variability in population genetic composition.

Approach, Evaluation and Methodology

Evaluate of population genetic structure of three species of salmonid in rivers and streams of the California Coastal region using novel molecular genetic datasets. Analysis of microsatellite and other genes was carried out in the Molecular Ecology Laboratory on the UC Santa Cruz Marine Sciences campus by a cooperative group of NOAA and JIMO researchers, as well as UCSC undergraduate and graduate students.

Research Accomplishments

In the present project period, we have continued the study of the relationships among extant steelhead populations in coastal California streams and rivers using molecular genetic techniques, extending the analysis to the South-Central and Southern California steelhead trout evolutionarily significant units (ESUs), and advancing more detailed studies of population genetic structure in large basins, including the Klamath and Russian Rivers. Project staff and collaborators have completed genotyping and quality control of 18 microsatellite markers in approximately 3500 trout, representing over 60 additional local populations and including both the northernmost (upper Klamath River) and southernmost (Santa Clara River, Topanga and Malibu Creeks) steelhead populations in California. Analyses of these data have produced several significant results. Among them, we have found in the southern trout population study that populations breeding above dams are largely descended from coastal steelhead and not from hatchery rainbow trout introduced for angling.

In this project period, we also finalized data collection at 18 microsatellite markers for coho salmon and expanded the samples analyzed to include a collection of temporally consistent juvenile population samples from most large coho salmon populations in California. The dataset now includes over 5000 fish from almost every extant population in California. The data allowed inference of population relationships and revealed higher-level genetic population structure (Figure 1). This structure indicates that the Southern Oregon/Northern California ESU contains at least two distinct genetic lineages: the coastal rivers of California, including the Eel, Mattole, etc., and the Klamath River.

In the present reporting period, laboratory work was also completed for the analysis of population genetic structure in chinook salmon from the California Coastal ESU. Almost 900 salmon from the major basins in this ESU, as well as from the Klamath, Central Valley Fall and Central Valley Spring ESUs, were genotyped at 17 microsatellite markers. Analyses of the completed data resolved population structure and indicate that the current ESU boundaries are appropriate, as all results indicated clear separation between samples from populations in the different ESUs. Nevertheless, genetic differentiation in Chinook salmon was estimated to be lower than in sympatric coho salmon or steelhead trout populations. In spite of this low differentiation, the dataset was sufficiently powerful to accurately identify most fish to population and, therefore, ESU of origin. This will allow use of this dataset in genetic stock identification analyses for the determination of ocean distribution of different Chinook salmon stocks, thereby allowing more efficient fishery management to simultaneously meet both harvest and conservation objectives.

The genetic population structure work described here has dramatically increased our understanding of the population history and migration patterns of California's coastal salmonid species, and has helped to counteract several suppositions based upon little data. The presence of a correlation between geographic and genetic distance observed in all three species (albeit weakly in Chinook salmon) indicates that distance-dependent migration (straying) is the primary mechanism of genetic structuring in California salmonids. The operation of hatcheries over the last century and the related inter-basin transfers have, therefore, not substantially disrupted historic population structure, except possibly in Chinook salmon. This indicates that inter-basin transfers are largely ineffective in establishing breeding populations and should not be viewed as a mechanism for supplementation of salmonid populations, with the possible exception of small populations in adjacent/proximal streams where extremely depressed population numbers may indicate that inbreeding is a greater risk than hybridization with fish from another river.

The results of this work have been quickly incorporated into ESA recovery planning and all of the datasets and analyses described above are either already integrated into recovery planning documents or will soon be. Most of the work completed to date focuses on the spatial component of population structure. It is imperative that future work evaluates the temporal component of population structure and establishes the quantity and quality of temporal genetic variance, so that these datasets can be used as baselines for future genetic monitoring in California of salmonid population size and composition.

Fig. 1 Factorial Correspondence Analysis of individual genotypes for California coho salmon from 17 populations. The analysis indicates that the Southern Oregon/Northern California ESU contains at least two distinct lineages.

Ocean and Estuarine Physiological Ecology of Salmon

Susan Sogard and Gary Griggs (UCSC)

NOAA Technical Contact: Churchill Grimes (NMFS)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management

Research Objectives and Specific Plans to Achieve Them

Determine spatial and temporal variability of physiological processes, ecological interactions, and the influences of environmental variables on salmonids in estuaries and the coastal ocean of California. Collect salmon, prey, and environmental data in estuaries and ocean; assess, growth, energy dynamics, feeding, and physiological condition in relation to environmental factors.

Approach, Evaluation and Methodology

Juvenile salmonids were surveyed and collected in estuaries and the coastal ocean of central California. Chinook salmon were obtained by surface trawl at the entrance and exit to the San Francisco Estuary and at locations along the coast from Pt. San Pedro to Pt. Arena out to a depth of 150m. In concert with trawling, plankton, neuston, chlorophyll and temperature-salinity by depth (CTD) data were collected. Another component of the ocean Chinook salmon study, determining stream of origin, was accomplished by determining the 87Sr/86Sr isotopic ratio of the juvenile portion of adult otoliths and comparing these values to those of water from Central Valley streams. Adult salmon for this study were sampled from commercial and recreations landings. In small estuaries (Redwood Creek, Marin County; Gazos Creek, San Mateo County; Scott Creek, Laguna Creek, San Lorenzo Rive, Soquel Creek, Aptos Creek, Santa Cruz County), coho salmon and steelhead were surveyed by snorkeling followed by seining to collect representative samples. Movement into the estuary was determined by collecting fish in a downstream migrant trap upstream of the estuary. Water quality and flow data were also recorded. For Chinook salmon, size and otolith-based age and growth data are used to determine growth. Energy content was assessed by protein and lipid class analyses, and feeding was evaluated by determining the volume and species composition of stomach contents. For steelhead and coho salmon, growth was measured by tag-recapture techniques using PIT (passive integrated transponder) tags, smoltification by gill Na+, K+-ATPase activity, and age by scale analysis. Thermal history of steelhead smolts was investigated by fitting fish with temperature archival tags, releasing them into Scott Creek estuary, recapturing the fish at a later time and recovering the data from the tag. Steelhead estuarine residence, and growth during residence, was assessed by microstructure and chemical analyses of scale samples. Transects of elemental ratios (e.g., Sr/Ca, Mn/Ca) across the scales are being investigated to determine their utility in recording estuary entrance and exit. Salmon data were analyzed in relation to oceanographic and hydrologic data to determine the relationships between physiological and ecological processes and environmental conditions. The research was conducted by UCSC staff, graduate students, and researchers from the NOAA Fisheries Santa Cruz Laboratory.

Research Accomplishments

Chinook salmon: Cruises in San Francisco Estuary during May and June, and along the central California coast in October 2004 and June 2005, collected 631 juvenile Chinook salmon. Juveniles have been examined, measured, and tissues excised for subsequent analyses. Stomach contents have been preserved and are waiting analysis. Age, growth, protein, and lipid class determinations are in progress. Plankton (65 tows), neuston (61 tows), CTD (113 casts), and other environmental data are presently being entered and subjected to QA/QC procedures. The analysis of ocean-caught adult Chinook salmon to determine natal origin and the composition of the ocean metapopulation has been completed.

Steelhead and coho salmon: Estuarine surveys were conducted monthly except at Scott Creek, where sampling was several times per month. More than 587 juvenile coho salmon and 2,181 juvenile steelhead were assessed. All juveniles greater than 65 mm fork length received a PIT tag. All fish were measured, weighed, had scales removed (age determination) and fin clipped (genetic sample); a representative sample at each time/location had a small gill filament sample removed for smoltification analysis. Following these procedures, fish were released. In Scott Creek estuary, 17 juvenile steelhead were fitted with temperature archival tags; four have been recaptured and their thermal history evaluated. For the estuarine residence study, scales have been prepared and mounted on glass slides and are presently being analyzed to determine age and estuarine entry and exit. Chemical analysis of scales collected during 2004 has been completed.

Results:
• Summarizing seven years of data, Chinook salmon emigrate from San Francisco Bay at 87.4±0.3 mm fork length (FL) and 7.5±0.1 g (n = 1379) in May and June and attain a size of 316±5 mm FL and 452±26 g at approximately one year of age in the ocean. Using protein and lipid concentrations data, this represents an export of 27.2±1.0 kJ of energy per fish leaving the freshwater and estuarine environment, and a gain of 960±101 kJ of energy per fish during their first ocean year (Fig 1.).

• Steelhead in coastal streams of central California demonstrate differential growth depending upon where they are in the watershed. Those that move to the estuary grow maximally during the late summer and fall (~0.5-0.8 mmd-1), whereas those in upstream habitats grow best during the spring (~0.2 mmd-1).
• Chemical analysis of scales from steelhead from Scott Creek, a central California coastal watershed, reveal clear identification of ocean entry, but not estuary entry, confounding the ability to use scales from returning adults to determine growth during estuary residence. However, size at ocean entry, based on scale microstructural analysis, of returning adults suggests that growth during the estuarine phase is critical to survival during the ocean phase of the animal's life history.
• Coho salmon extended their range southward to include Laguna Creek in Santa Cruz County. Both young-of-the-year and yearling coho were observed in the estuary, indicating successful reproduction of at least two year classes. Previously the southern extent was Scott Creek, 6 km to the north.
• From tag-recapture data, growth rates varied greatly among the seven estuaries sampled, ranging from 0.1 mmd-1 in Redwood Creek to 1.3 mmd-1 in Aptos Creek.

The results of our study can be used to better understand the biology of Endangered Species Act listed salmonids in California, and to use this information to facilitate recovery and management of the stocks. Most data on salmonid physiological ecology originate from populations in the Pacific Northwest, the center of the taxon's biodistribution. Physiological performance and ecological requirements often vary at the margin of a species distribution. Knowledge of these allows resource managers to make more scientifically informed decisions on appropriate land use and aquatic developmental activities. Knowledge of energy content can be used to determine interannual variation, the consequences of that variation, and the influence of environmental conditions on population health and growth.
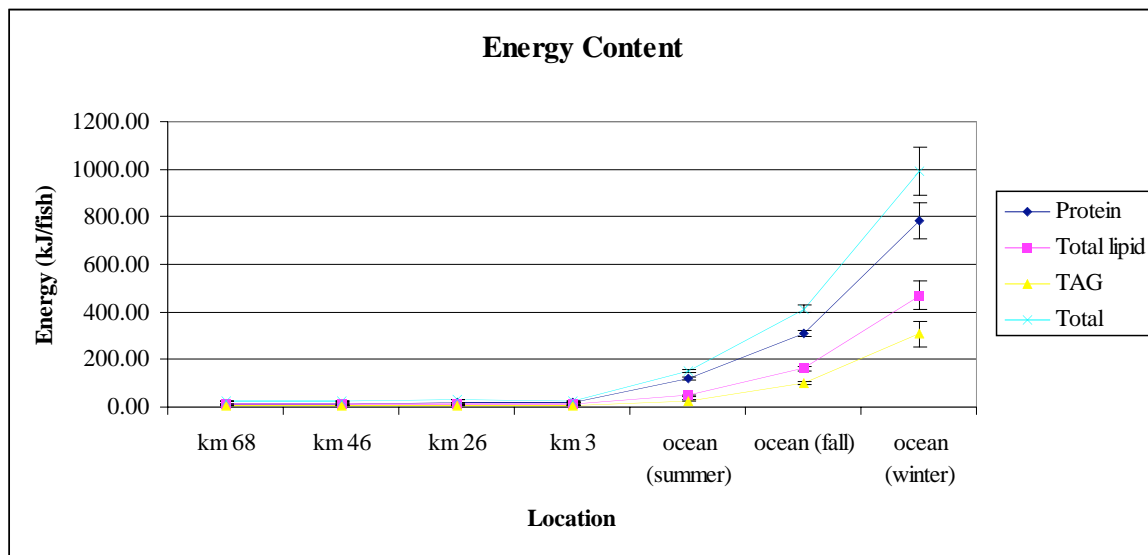
Fig. 1 Energy content of juvenile Chinook salmon from California's Central Valley during outmigration and first ocean year. Locations designated by km (kilometers) are distance from ocean at the Golden Gate. Ocean data are from fish collected between Pt. San Pedro and Pt. Arena on continental shelf. TAG is triacylglycerols.

Early Life History Studies in Rockfish

Susan Sogard and Gary Griggs (UCSC)

NOAA Technical Contact: Churchill Grimes (NMFS)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management

Research Objectives and Specific Plans to Achieve Them

Our overall objective is to determine factors influencing survival of early life history stages of rockfishes. Specific plans include identifying species differences in larval quality and maternal effects on larval performance. We use experimental methods to assess larval size and condition at parturition, growth rates, mortality rates, and swimming performance. These traits are related to age of females.

Approach, Evaluation and Methodology

We collect mature female rockfish using hook and line gear, then hold them in individual tanks in a flowthrough seawater system. Parturition of larvae takes place at night. The following morning, a sample of larvae is measure for length, body depth, and the volume of the oil globule, a packet of high energy TAG (triacylglycerol) lipids. Live larvae are counted and held without food to determine starvation resistance. In additional tanks, live larvae are maintained on a diet of cultured rotifers and measured every 4 days to estimate growth capacity. Swimming capacity and response to disturbance (startle distance and speed) are recorded using video analysis.

Research Accomplishments

Thus far we have examined larval quality in five species of Sebastes: Blue, olive, kelp, gopher, and yellowtail females have been successfully held to parturition in laboratory tanks. We have discovered several intriguing differences across these species. Most notable is an apparent trade-off between larval size and larval condition, the latter indexed by the size of the oil globule (Fig. 1). These differences appear to correspond to the season when females release their larvae into the plankton. Blue, olive, and yellowtail typically spawn in the winter, prior to the major period of upwelling. At this time primary production is typically much lower than during spring/summer upwelling. The three winter spawners we examined produce larvae with large oil globules but small body size. Our performance measurements demonstrate that the TAG reserves in the oil globule provide larvae with enhanced resistance to starvation. Gopher and kelp rockfish, in contrast, release larvae in late spring, in the midst of the upwelling season when productivity is typically the highest of the year. Their larvae had much smaller oil globules than the winter spawners, but were larger in body size. In our experiments testing performance, larger larvae had enhanced growth responses, better swimming capabilities, and responded better to disturbance compared to smaller larvae. Thus, winter spawners appear to trade-off growth and swimming performance for greater resistance to starvation, whereas spring/summer spawners make the opposite trade-off. We propose that these differences are a function of ocean conditions at the time of larval release. These studies will continue as we examine in more detail the role of maternal age in further refining the timing of parturition.

Our results suggest that the seasonal timing of parturition is important in determining the probability of survival for larval rockfishes. Improved understanding of subtle differences in reproductive strategies and larval provisioning among species will add to our understanding of the factors underlying recruitment variability in rockfishes and in our ability to predict how changes in oceanographic conditions will affect rockfish stocks. Our continued study of maternal effects will aid in understanding the importance of maintaining age diversity in stocks of rockfish. Recommendations for further study include assessment of larval quality in deep water species of Sebastes (all of the species examined thus far reside in shallow waters), detailed analysis of growth and survival under differing temperature and prey conditions, and further assessment of age-dependent effects on timing of parturition and larval quality.
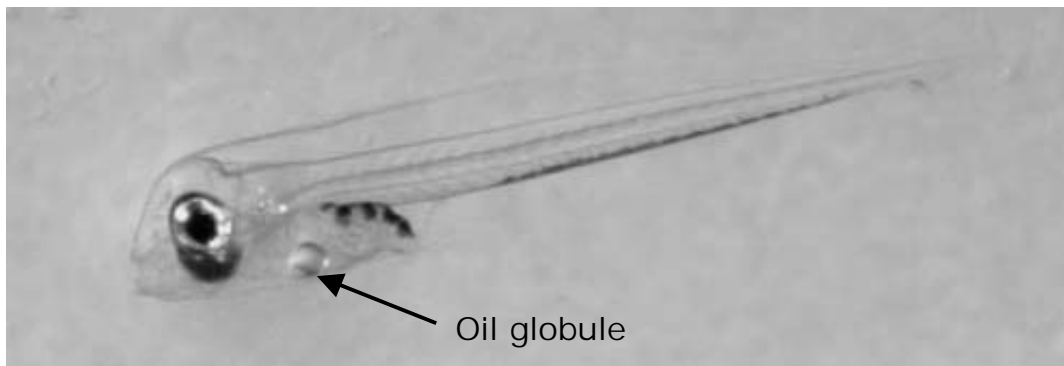

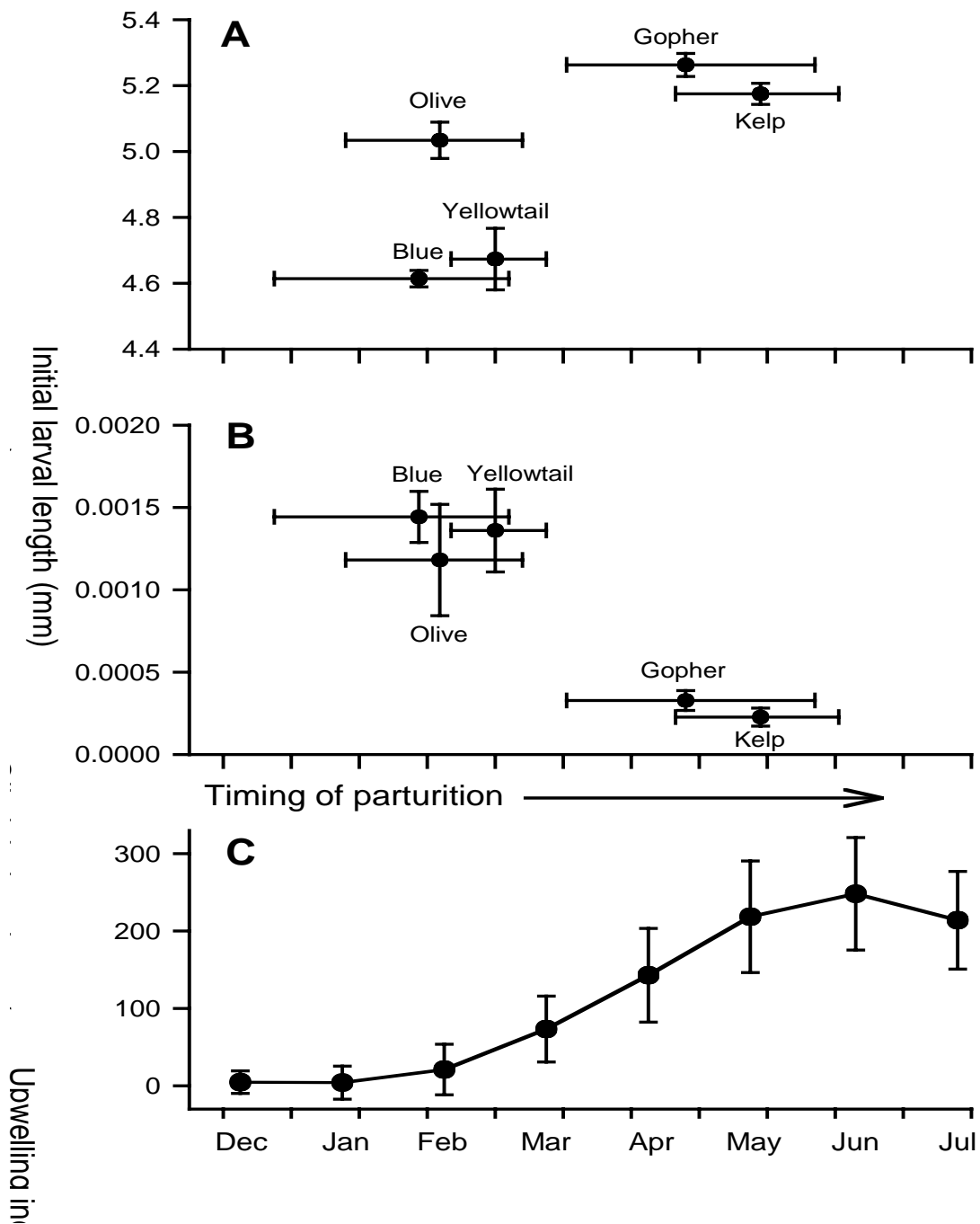Fig. 1 Larval blue rockfish at parturition. Arrow points to oil globule.

Fig. 2 Mean (and S.E.) of larval length (A) and oil globule volume (B) relative to the timing of parturition (mean and range) for five species of rockfishes in laboratory experiments. Graph C shows mean Bakun upwelling index (and S.D.) along the central coast from 1946 to 2004.

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Groundfish Ecology Cruise Program

Pete Adams (UCSC)

NOAA Technical Contact: Churchill Grimes (NMFS)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean
Resources Through an Ecosystem Approach to Management

Research Objectives and Specific Plans to Achieve Them

This study has several objectives including:
- develop basic life history data for as many groundfish species as possible
- study commercial fishing methodology as it relates to research survey design
- examine commercial fishing gear effectiveness

These objectives are addressed through a series of monthly cruises aboard a chartered commercial trawler and longline vessel. Each vessel is operated by experienced local fishermen using standard fishing practices. The exact fishing location for each cruise is largely determined by the captain based on his knowledge of the area.

The data collected by this study is essential for management of the groundfish fishery. At this time, four separate stock assessments are using data collected by this program. In addition, the data collected will allow us to improve existing data by allowing age validation studies to be conducted on species already being aged.

Approach, Evaluation and Methodology

Typically, two cruises are conducted each month: a trawl cruise and a longline cruise. Each trawl cruise conducts 5, one-hour tows in various depths from 20 meters to 500 meters. Each longline cruise consists of 5 or 6 sets with a variable number of hooks per set based on standard commercial fishing practices for the depths occupied.

During the trawl cruise, samples of groundfish are collected and placed on ice for examination at the laboratory. The species composition of the catch is estimated using various methods based on the size of the catch. Some species are measured at sea including California halibut and lingcod. When skates are caught in good condition, they are tagged and injected with oxytetracycline. On some cruises, specific fishing practices are tested, for example: day versus night trawling in shallow water. The speed and direction of each tow is determined by the captain of the vessel using normal commercial fishing practices. The only substantial differences between research tows and commercial tows is that we use a codend liner with ¼" mesh, and our tows are limited to 1 hour. Sharks and skates of various species are returned to the Pacific Shark Research Center for further workup. All other specimens are returned to the Santa Cruz Laboratory.

During the longline cruise, we set gear at various depths depending on the species mix we are interested in. Our deepest set is in about 500 meters of water in a canyon. We typically set 6000 hooks and have a soak time of about 6 hours. Temperature Depth Recorders (TDRs) are placed at regular intervals along the line. When a TDR is brought aboard, we enumerate what is on the next 50 hooks, including whether there is still bait on the hook. When the TDR data has been downloaded, we can determine exactly how long the gear was fishing on the bottom as well as what depth it was at. For shelf rockfish, we typically set 2 or 3 lines of about 750 hooks each and allow them to soak for about 1 hour. A TDR is placed on each one to obtain the precise depth. For nearshore species, we typically set 2 lines of 500 hooks and soak the gear for about 45 minutes. When the gear is recovered, we attempt to tag and inject (oxytetracycline) as many fish as possible. Those which are in poor condition are returned to the laboratory. On one cruise, we placed acoustic tags on 19 fish and we are currently monitoring their movements on the local nearshore reefs.

In the laboratory, we weigh, measure, sex, and determine the sexual maturity stage of 50 fish per species per haul. We remove otoliths from 25 fish per species per haul as well. In addition, if ovaries are in late development, we remove the ovaries for fecundity studies. A tissue sample is collected from each fish for genetic analysis.

Ongoing analysis of the data will include aging of all fish, as well as fecundity studies. The genetic studies will be used to determine whether hybridization is occurring for some species. In addition, there is some data to suggest that one species of rockfish (vermillion) may in fact be 2 species. If we can establish that, and determine a method of readily identifying the two species, we will be able to determine if their basic life history parameters are sufficiently different to require them to be assessed separately.

Research Accomplishments

- Collected data on 82 species.
- Developed age and growth parameters for the following species: sand sole, greenspotted rockfish, vermillion rockfish, starry flounder, and gopher rockfish.
- Developed fecundity estimates for greenspotted rockfish and rex sole.
- Discovered seasonal maturity and size at maturity for 23 species.
- Tagged more than 700 fish from 13 species.
- Contribution to current stock assessments for the following species, which rely heavily on data collected by the program: vermillion rockfish, starry flounder, gopher rockfish, kelp greenling

Fig. 1 Two researchers implanting an acoustic tag in a gopher rockfish (Sebastes carnatus). The tagging was conducted aboard a chartered longline vessel.

Cooperative Studies of Pacific Coast Salmon: NOAA Fisheries and the University of California, Santa Cruz

Pete Adams (UCSC)

NOAA Technical Contact: Churchill Grimes (NMFS)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management

Research Objectives and Specific Plans to Achieve Them

Salmon Population Analysis Team (SPAT) scientists conduct research needed to support (1) salmonid conservation and recovery planning under the Endangered Species Act (ESA) and (2) management of salmonid fishery and harvests. In addition, Team personnel conduct basic research that will provide the underlying theoretical structure of these activities in order to improve the management of salmonids in the future. Specific goals include: to collect or to coordinate collection of critical population distribution and abundance data needed for assessments of salmonid populations; to establish appropriate and statistically robust survey methods and population estimators for use in salmon research and management; to investigate critical salmon life history characteristics (abundance, distribution, mortality, straying, etc.) needed for a comprehensive management approach to Pacific salmon and steelhead; to develop methods for modeling population viability and metapopulation dynamics for use in ESA assessments; and to provide salmon harvest management guidance, through modeling and focused biological studies.

To achieve these goals, SPAT scientists engage in research that integrates four broad areas: conservation biology, population ecology, spatial ecology, and quantitative methods. Within these areas, projects include field studies, spatial analysis using Geographic Information Systems (GIS), modeling, and the development of sampling and statistical methods.

Approach, Evaluation and Methodology

SPAT scientists employ a wide variety of field sampling and quantitative methods to achieve specific research objectives. Methods include observational and experimental field studies, statistical analysis, spatial analysis using GIS, and modeling. Specific study designs are dictated by the particular hypotheses being tested. SPAT personnel engaged in six field studies between July 2004-June 2005: (1) seasonal patterns of stream food webs and prey availability/use by juvenile *O. mykiss* in Big Sur; (2) population dynamics of *O. mykiss* is small coastal basins; (3) effects of temperature and food rations on *O. mykiss* growth and survival in southern California; (4) temperature and discharge patterns in central California coastal streams; (5) genetic structure of *O. mykiss* above and below dams in southern California; and (6) effects of fish predation and carbonate crust on stream food webs. In addition to these field studies, the Team engaged in or completed a variety of projects related to technical recovery planning for California salmonid populations, harvest management, statistical analysis, life-history analysis using otolith microchemistry, historical and present distributions of salmonids in California, GIS-based spatial analysis, and theoretical ecology/modeling.

Research Accomplishments

SPAT personnel completed five field studies and initiated another long-term field study, completed a variety of spatial analyses using GIS to identify potentially suitable habitat for salmonids throughout California, and completed several modeling and statistical projects. Results were presented in 17 publications and 16 presentations. In addition to these research activities, SPAT scientists led NOAA Fisheries Technical Recovery Teams, served on Biological Review Teams engaged in conservation and recovery planning for threatened and endangered stocks of anadromous salmonids, and served on Klamath River Technical Advisory Team and Salmon Technical Team to provide stock assessment and harvest management support.

Fig. 1 NOAA/JIMO fisheries biologist snorkeling to estimate juvenile salmonid abundance in small streams, northern California.

Shipboard Monitoring of the California Current System Off Central California

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2) Naval Postgraduate School

NOAA Technical Contact: Churchill Grimes (NMFS)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Research Objectives and Specific Plans to Achieve Them

A collaboration between the Monterey Bay Aquarium Research Institute (MBARI), the Naval Postgraduate School (NPS), the University of California, Santa Cruz (UCSC), and NOAA/NMFS has led to continued quarterly occupations of historical CalCOFI lines off central California.

Approach, Evaluation and Methodology

During the period between August 2004 and August 2005, in cooperation with the NMFS, quarterly shipboard measurements along central California were continued in an effort to further understand the relationship between physical circulation and biological consequences in this critical region that is the site for the majority of the nutrient input to the surface waters of the California Current System.

Research Accomplishments

Specifically, the following objectives were achieved:
- Physical and biological measurements were made along Line 67 & 60 in October 2004 using the *R/V Pt. Sur*
- Personnel were placed on NOAA Ship *David Starr Jordan* to collect physical, chemical and phytoplankton measurements along the northern portion of the CalCOFI grid up to San Francisco in the Winter and Spring of 2005
- Physical and biological measurements were made along Line 67 & 60 in July 2005 using *the R/V Western Flyer*

Measurements Taken During the Fall 2004 and July 2005 cruises included:
- Continuous underway sampling of SST, SSS, Fluorescence, PCO2, and meteorological parameters
- CTD/rosette casts including assays for nutrients (nitrate, nitrite, phosphate and silicate), chlorophyll-a, primary production, phytoplankton taxonomy and cell counts
- Bongo tows (oblique) to 210m to sample macrozooplankton/icthyoplankton – processed for zooplankton biovolume and krill abundance and species composition and subsequently archived for further taxonomic analysis with NMFS La Jolla

Additionally this work also supported the collection and analysis of chlorophyll-a and nutrients from the northern lines occupied by the NOAA Ship *David Starr Jordan* during the Winter and Spring of 2005
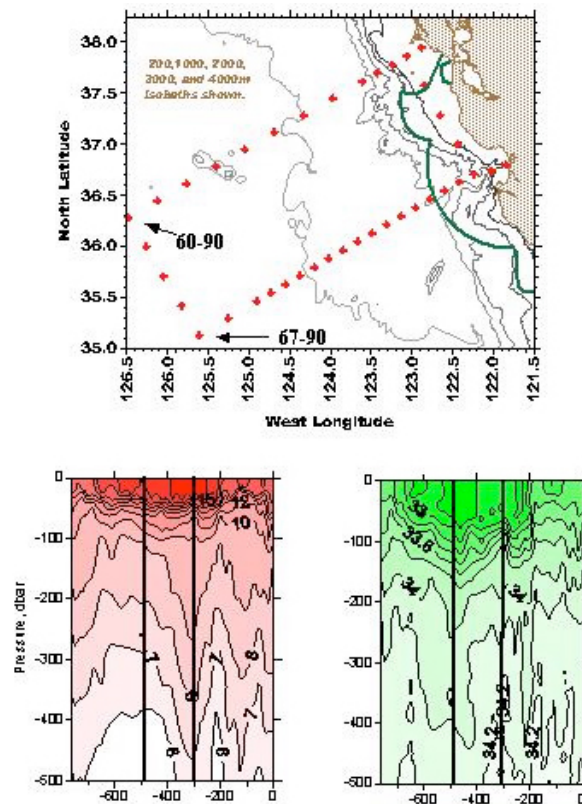
Figure 1. Top: Sampling Grid for 2004 & 2005 cruises. Bottom: Physical properties around the box shown in top figure, October 24-29, 2004. The vertical lines correspond to the offshore stations 67-90 (right) and 60-90 (left). Left. Temperature, C, contour interval is 1 C. Right. Salinity, contour interval is S=0.1 for 34.0<S<34.2 and S=0.2 otherwise.
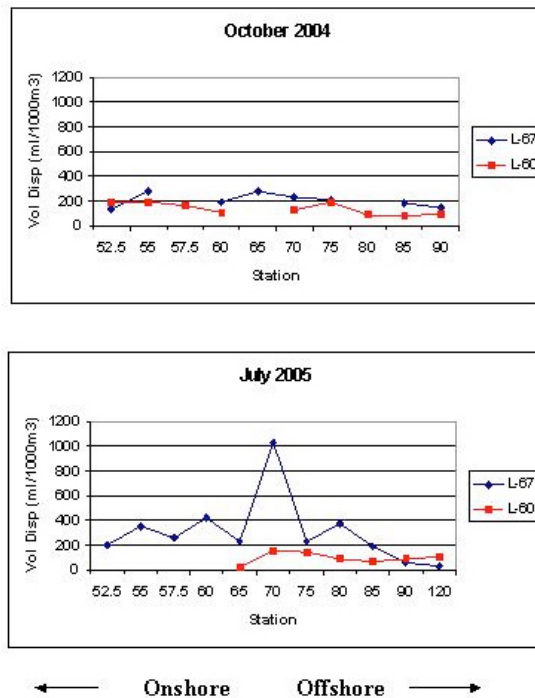
Figure 2. Zooplankton volume displacements for CalCOFI Lines L-67 and L-60 during the October 2004 and July 2005 quarterly surveys. Note some stations were not sampled due to bad weather

Phytoplankton Studies in Cooperation with the U.S. Antarctic Marine Living Resources (AMLR) Program

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NOAA Technical Contact: Rennie Holt (SWFSC)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management

Research Objectives and Specific Plans to Achieve Them

Our overall objective is to obtain sufficient data on the biomass distribution (horizontal and vertical) of phytoplankton so that the inter-relationships between the primary producers, the physical/chemical/optical environment, and the food requirements for krill may be better understood. Our shipboard studies utilized the following:

- sensors that automatically record data in a central computer (operated by the physical oceanography component of AMLR)
- discrete water samples for measurement of chlorophyll concentration in the euphotic zone.
- images of chlorophyll distributions for the Drake Passage and AMLR survey area from the MODIS (Aqua) satellite.

Approach, Evaluation and Methodology

The Antarctic Marine Living Resources (AMLR) program is the US component of an international program (CCAMLR) to assess the stock and production of krill in the Southern Ocean and the impact of their harvest upon higher trophic levels. The AMLR study area around Elephant Island is known to be very productive for krill and higher trophic levels, and has been one of the major areas for commercial harvesting of krill. The reasons why this area is so rich in krill and higher trophic levels such as birds and seals are not well understood, but it is thought to be related to the varied bottom topography (including extensive shelf regions) and to the existence of mixing zones between the various water masses encountered in this area. Much of the waters in the AMLR study area thus have high inorganic nutrients, including iron, and fairly well developed upper mixed layers. These conditions result in high phytoplankton biomass and in high, sustained rates of primary production. Our participation with AMLR since 1990 has involved work aboard ship mid-January through mid-March, with ship operations including two ~28 day Legs. For each Leg during 2004, a CTD carousel and independent profiling units were used to obtain samples of the water column for analyses as well as to obtain data from various profiling sensors as listed below:

- Water samples were obtained from 10-liter Niskin bottles (with Teflon covered springs) which were closed at 10 standard depths (5, 10, 15, 20, 30, 40, 50, 75, 100, and 200m) from every station upcast of the CTD/rosette unit.
- A Sea Tech transmissometer was used to determine the attenuation of collimated light (by both scattering and absorption) during CTD casts.
- A Biospherical QCP200L profiling PAR (photosynthetic available radiation) sensor was used to measure the in situ light regime.

Research Accomplishments

MODIS-Aqua Satellite imagery monthly composites indicate that the area of the pelagic Drake Passage west of the Shackelton Fracture Zone had exceptionally low chlorophyll concentrations as measured during the January-March AMLR field season. This is in contrast to the much richer conditions that were apparent in December. These observations were corroborated by field measurements. In addition, higher surface chl-a concentrations occurred along the shelf and shelf-break (e.g., coastal) regions and in the Bransfield Strait. Very rich blooming also occurred to the northeast of the AMLR survey area in the Scotia Sea.

Two different types of PAR sensors to measure incident light while underway have been used during AMLR cruises. Prior to 2000, a BSI Model QSR-240 scalar PAR sensor was used, and after which, a Li-core Model LI-190 cosine PAR sensor used. A scalar sensor measures light from all directions (e.g., direct + scattered light). A cosine PAR sensor only measures light from a relatively singular (e.g., direct) direction (~80° angle of incidence). For shipboard studies, it is usually desirable to use a scalar sensor primarily because the rolling of a ship can result with a cosine sensor obtaining highly variable data on sunny days. This season we took underway measurements using both sensors, and found they agreed well, however the Li-cor had slightly higher (~5%) values. The average intensity of PAR during Leg I was much less than half the theoretical maxima, indicating that overcast and foggy conditions existed during most of this cruise. Such conditions scatter the incident light, and could be the explanation for the good comparison between the different types of PAR sensors.

Pelagic waters north of the South Shetland Islands were found to have a different phytoplankton community size-structure than populations analyzed in shelf and shelf-break waters and Bransfield Strait waters. Regardless that total chlorophyll of Bransfield Strait and shelf and shelf-break areas were of near-bloom to bloom (e.g., >1 mg chl-a m-3) concentrations, populations were dominated by nanoplankton (<10 µm diameters) cells. This is interesting in light of the dogma that nanoplankton dominate low biomass and large cells usually dominate high biomass regions of the Southern Ocean. Taxonomic investigation by examination with microscope for these samples is currently in progress to help elucidate differences between phytoplankton communities for Drake Passage and "other" waters.

Samples for nutrient chemistry, phytoplankton taxonomy and dissolved organic carbon (DOC) are in the process of being analyzed at the time of this report.
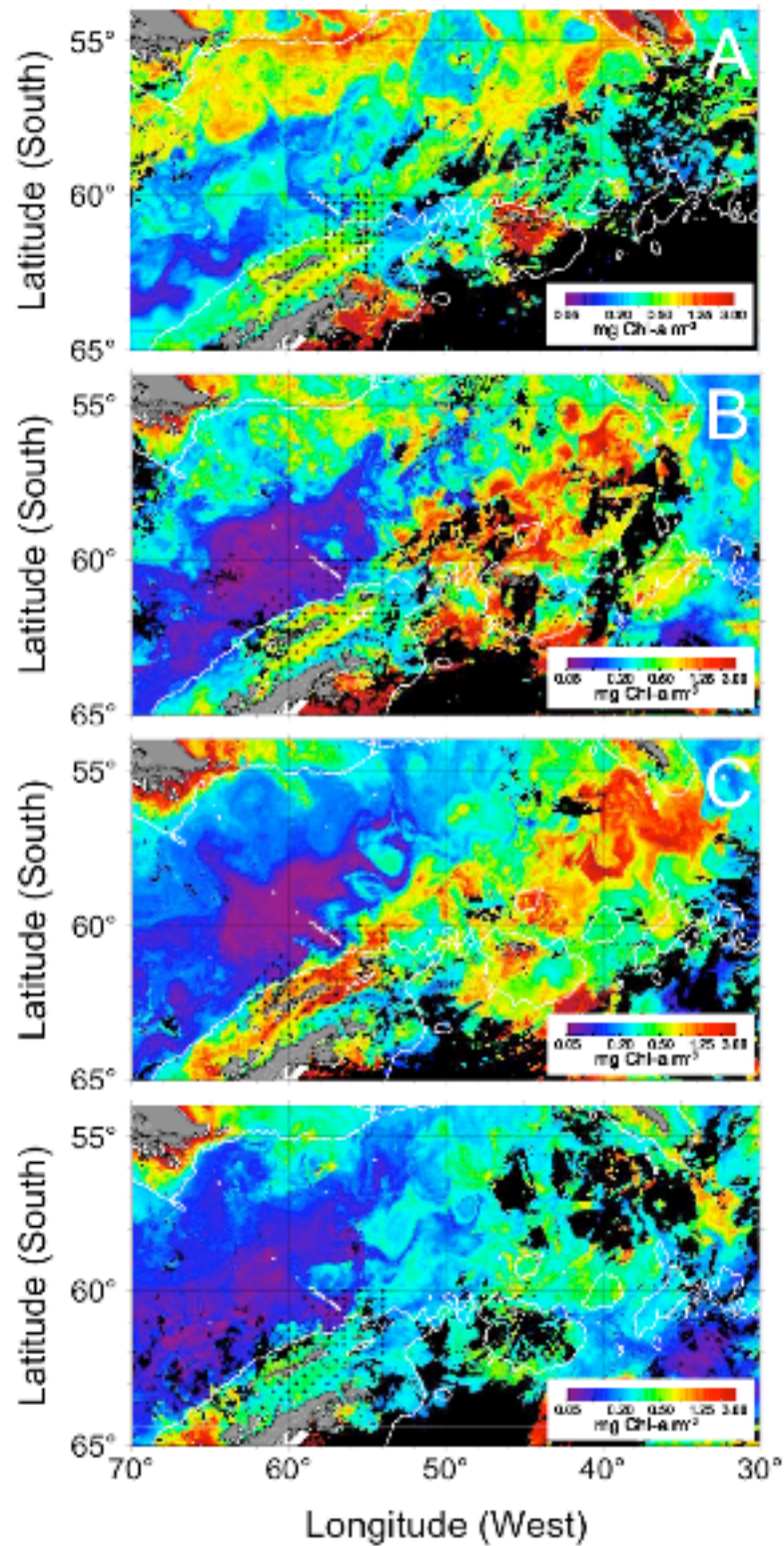
Fig. 1 Surface chlorophyll concentrations in the AMLR survey area (grid of symbols) and surrounding area as obtained by MODIS-AQUA satellite for December (A), January (B), February (C), and March (D), 2005. The 2000 meter contours shown as white lines, black areas indicate insignificant data due to cloud cover.

Dynamics and Mechanics of HAB Dinoflagellate Mortality by Algicidal Bacteria

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NOAA Technical Contact: Susan Banahan (COP)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources through Ecosystem-based Management

Research Objectives and Specific Plans to Achieve Them

Our objective is to quantify the ability of algae-killing bacteria belonging to the genus Cytophaga to influence the population dynamics of the red-tide forming dinoflagellate Lingulodinium polyedrum. We will combine controlled microcosm experiments using cultures of axenic phytoplankton and bacteria with simple models to determine the critical dynamics and mechanisms that govern this algal-bacterial interaction. Concurrently, we will then use DNA-probes specific for L. polyedrum-killing bacteria to quantify their abundances in the field and their localization with respect to the dinoflagellate cells.

Research Accomplishments

Using the ALC1 bacterium isolated during year 1 as a model system to understand algal-bacterial interactions in the context of harmful algal blooms, we have focused on two major efforts: 1) a mechanistic understanding of the nature of the interaction in the laboratory, and 2) on the potential significance of this interaction in nature. In addressing the first goal, we have determined that ALC1 releases a dissolved serine protease in the medium which inhibits the flagellar motility of Lingulodinium polyedrum. After the dinoflagellates are no longer motile, the bacterium colonizes, eventually leading to ecdysis and cell death. We are currently investigating the ability of stationary phase L. polyedrum cells to resist this motility inhibition. In addressing the second goal, we have designed and tested a DNA probe specific to ALC1 and, using TSA-FISH, have quantified the abundance and distribution of this bacterium in the field during the 2003 red tide and during a 10-month non-bloom period in 2004. We have also isolated several other bacteria which also cause growth inhibition of l. polyedrum to determine if this ability is widespread.

Fig. 1
Epifluorescence micrographs of field samples: left, ALC1-specific probe (green); right, DNA stained with DAPI (blue)

Climate-driven Bottom-up Processes and Killer Whale Abundance as Factors in Steller Sea Lion Population Trends in the Aleutian Islands

George L. Hunt, Jr. (UCI)

NOAA Technical Contact: John Calder (OAR)
Links to NOAA Strategic Plan:
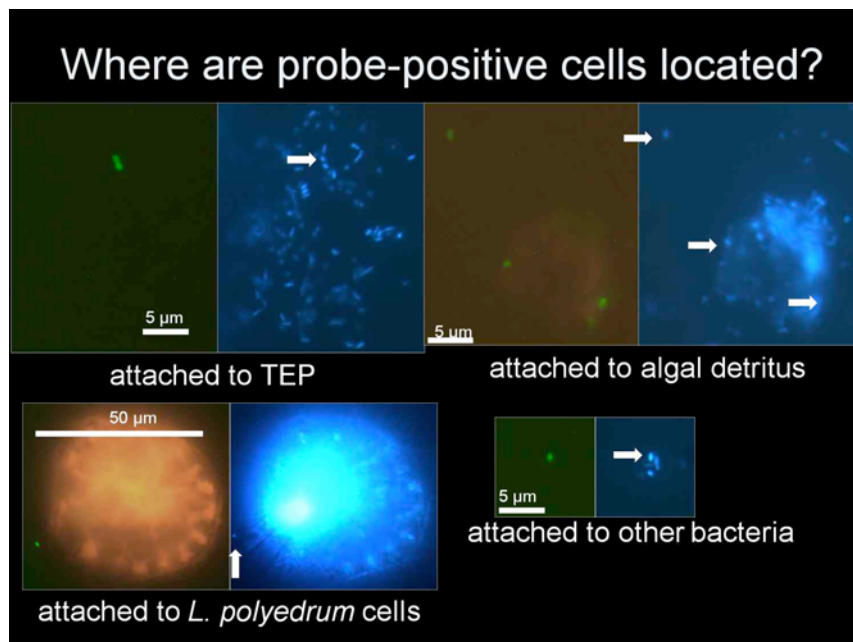NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management

Research Objectives and Specific Plans to Achieve Them

Due to their continuing population decline, the western stock of Steller sea lions (Eumetopias jubatus) are now listed as an endangered species. Several hypotheses have been generated to explain the declines in populations from Kodiak Island, the Alaskan Peninsula and the Aleutian Island Arc. These hypotheses include: 1) Commercial fisheries act as competitors for a significant fraction of the Steller sea lions' dietary requirements, 2) Increased predation by killer whales (Orcinus orca) has influenced trends in sea lion populations, and 3) Changes in climate have affected the productivity of the sea-lion habitat, and thus diminished the abundance or availability of prey for sea lions, particularly in the western portion of their range. The necessary management actions to mitigate the possible effects of the fisheries have severely restricted the inshore portion of the commercial groundfish fishery. To improve the basis for future management decisions regarding commercial fisheries, more information was required about how killer whales and climate variations impact the ecosystem on which Steller sea lions depend.

Approach, Evaluation and Methodology

We proposed an integrated multidisciplinary research effort to examine the possible effects of killer whales and climate change on Steller sea lions in the Aleutian Islands. To this end, we quantified primary production, zooplankton distribution and abundance, seabird foraging as an indicator of prey concentrations, and killer whale distribution, and abundance in regions of the Aleutian Islands where sea lion populations are stable and where they are declining. In addition, we collaborated with Phyllis Stabeno, who quantified nutrient concentrations, hydrography and currents within the study areas, and the linkage between the effects of climate change in the North Pacific Ocean and physical responses in the critical habitat of the sea lions. We will also collaborated with Sue Moore, who provided data on the distribution and abundance of cetaceans at sea, and Beth Sinclair and Tom Loughlin of the National Marine Mammal Laboratory who provided satellite tracking data on the foraging distributions of Steller sea lions and enema and scat analyses of their diets. This study was the first multi-disciplinary, integrated examination of the ecosystem in the critical habitat of the western population of the Steller sea lion.

Research Accomplishments

During cruises to the eastern and central Aleutian Island Passes in 2001 and 2002, we documented that 1) Samalga Pass was the westernmost pass with a significant northward flow of Alaska Coastal Current Water; 2) there is a strong east-west gradient in zooplankton species composition; 3) there is a strong east-west shift in species composition of marine birds and their diets; and 4) there are strong seasonal and east-west variations in the species composition and abundance of cetaceans. In both years, we saw very few pinnipeds in the water anywhere in our study area. We had remarkable opportunities to observe foraging seabirds in a number of passes, but the most impressive occurred in 2002 when we encountered extraordinarily large aggregations of shearwaters foraging on euphausiids at frontal structures at the northwest corner of Unimak Pass. There were more than 100 humpback whales amongst the shearwaters. A remarkable concentration of killer whales was found foraging on fish (that appeared to be salmon) in Samalga Pass. Several groups of what were apparently transient-ecotype killer whales were encountered feeding on a gray whale calf in Unimak Pass.

During 2004/2005, we completed manuscript production and review of 18 papers for a Supplemental volume of Fisheries Oceanography that will be published in late 2005. The volume consists of papers by investigators supported by the JIMO grant to G.L. Hunt, by investigators supported with Sea Lion funding to participate in the

cruises of 2001 and 2002, and by investigators studying the Aleutian marine ecosystem who were not connected directly with our research program. The result is a benchmark volume on the marine ecosystem of the eastern and central Aleutian Archipelago.

While there have been a number of isolated, historical studies of the marine ecosystem of the eastern and central Aleutian Archipelago, the results presented in this supplemental volume of Fisheries Oceanography represent the first integrated ecosystem study of this productive region. In addition to observations on physical, chemical and lower trophic level characteristics of the region, papers are presented on unique, cold-water corals that have colonized the deeper Aleutian Passes, the paleo-climate of the North Pacific, and studies of the fish, birds and mammals that inhabit this region.

A single integrating factor was found: a division between the eastern and central passes at Samalga Pass, with the eastern passes being more shelf-like and those to the west more oceanic. Specifically, east of Samalga Pass there are mainly neritic zooplankton species, which support short-tailed shearwaters and high numbers of fish species. In contrast, west of Samalga there are mainly oceanic zooplankton, which provide food for northern fulmars and auklets, and fewer fish species. Euphausiids are important in diets of fish to the east of Samalga Pass, while copepods and myctophids are important to their diets to the west. Similarly, pollock are the major prey of sea lions in the eastern part of study area, and Atka mackerel fill that role to the west. There was also a marked division in the distribution of sperm whales, with none found east of the pass, and a greater diversity of cold-water corals and sponges west of Samalga Pass.

Major findings include a better understanding of the mechanisms that control flow through the passes and the magnitude of that flow; the importance of the medium-size passes (water depth between 130 and 200 m) in supplying nutrients to the Bering Sea euphotic zone; the importance of the small and medium-size passes in providing foraging for birds and mammals; recognition that the Aleutians may support the greatest abundance and diversity of cold-water corals in the world; and, that during the last millennia, climate variability has impacted the ecosystem on many occasions.

A Joint Program for Training and Research in Marine Resource Management Modeling

James E. Wilen, Louis Botsford and Alan Hastings (UCD)

NOAA Technical Contact: Roger Hewitt (NMFS/SWFSC)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management

RESEARCH OBJECTIVES AND SPECIFIC PLANS TO ACHIEVE THEM

This project has two primary objectives: The first is to train Ph.D. level students from both biology and economics in the tools of quantitative fishery science in order to develop expertise necessary to better address management policy issues in a modern context. The second is to engage in applied policy oriented fisheries management science, particularly by integrating concepts from biology, stock assessment, economics, and policy analysis. Both objectives are being addressed with a new graduate program of study that integrates ecological and economic theory, and teaches methods of model development, data gathering, model estimation and calibration, and simulation methods. In addition, a collaborative fisheries research program has been developed to engage students and PIs in areas of interest to the Southwest Fisheries Science Center specifically, and in areas of broader interest to the fisheries management community.

APPROACH/EVALUATION AND METHODOLOGY

All three Co-PIs have been involved with supervising and instructing PhD students in both the Ecology and Resource Economics programs as well as in joint and individual research on fisheries management issues. Much of the research program has been developed in collaboration with scientists at the Southwest Fisheries Science Center, dealing with important regional issues including difficult rockfish management problems.

RESEARCH ACCOMPLISHMENTS

All three co-PIs have individual and joint research programs in progress that focuses on a range of basic and applied scientific issues underlying important fisheries management issues. One area of interest to all three co-PIs concerns developing understanding of spatial/dynamic processes in marine systems. Spatial dynamic processes are crucial to stock dynamics and to spatial abundance patterns. In addition, spatial dynamic processes are critical components to important policy questions, including marine protected area siting decisions. Botsford and Hastings are continuing to develop and explore conceptual models of larval dispersal in order to understand how areas that encompass species with various kinds of dispersal enhance the persistence of the population. Wilen and Botsford are continuing joint research on the Northern California Red Sea Urchin fishery with a unique fully spatial and dynamic model that links up a biological model with an economic model of decision-making. The model is being used to generate new insights about marine reserve siting, and the manner in which fishermen movement is important to reserve establishment. Wilen and a former student have continued using the urchin data set developed for the modeling project in order to explore further hypotheses about fishermen behavior. One direction taken this period has been to explore how fishermen perceive physical risks in diving, and whether observed physical and financial risk-taking behavior seems correlated. Wilen has also been engaged with other scientists studying the general problem of optimizing systems characterized by spatial/dynamic processes. Wilen organized a second international conference on bioeconomic modeling of spatial/dynamic systems in Trieste Italy, sponsored by the Beijer Institute in Stockholm. The conference brought applied mathematicians, quantitative ecologists, physicists, and natural resource economists together to discuss strategies for modeling dispersal, invasive species and invasive pests, and epidemics. Both Hastings and Botsford are also engaged in understanding how to judge a population's viability under sparse data conditions as well as exploring how to make management decisions in the face of the kinds of uncertainty typically faced by managers. Students supported by the project are involved in various aspects of stock assessment research for California rockfish, in collaboration with scientists at the Southwest Fisheries Science Center in La Jolla. This work includes estimation of catchability curves for different rockfish species, using diving observations, fish tagging, and experimental fishing. Another project explores methods for identifying lifetime egg production parameters in situations where data are sparse. Lifetime egg production parameters for Cow Cod have been computed, using two size distributions from early and current stages of the fishery's development. This work is useful for developing indices of a population's persistence potential in order to quantify the status of populations thought vulnerable to collapse. Wilen has begun research investigating the efficacy of harvester cooperatives as co-management institutions. These have recently been adopted in two important fisheries off the Pacific (Whiting and Being Sea Pollock) and the focus of the work is to understand how incentives of participants internal to the coop change as a result. Two graduate students are investigating harvester cooperatives in the near shore fisheries off Chile and Japan, aiming to understand both how coops determine fishing practices and marketing strategies, and also how coops affect biological and economic health. A final project is investigating methods of altering bycatch by changing skipper behavior rather than by focusing on technological solutions. This project is modeling the success of some voluntary programs adopted in Alaskan groundfish fisheries, using an extensive observer-based data set on landings, location, and species composition.

Right Whale Studies in the Gulf of Alaska and Bering Sea

John Hildebrand (SIO)

NOAA Technical Contact: Sue Moore (NMFS/AFSC)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management

Research Objectives and Specific Plans to Achieve Them

This project supported the processing of passive acoustic data from the southeastern Bering Sea and Gulf of Alaska to investigate the behavioral ecology of baleen whales occurring in the area. The priority species was the North Pacific right whale (*Eubalaena japonica*); research is also underway on fin whales (*Balaenoptera physalus*). The central goals of the data processing portion of the project were to 1) use passively recorded

acoustic data, supplemented by visual data collected during NMFS surveys, to characterize the abundance, distribution and acoustic behavior of right whales in the Bering Sea, and 2) to relate right whale distributions to oceanographic variables using other existing data sets. The project also funded outreach activities, including travel to visit schools in traditional whaling communities around the Bering Sea, and contributions to educational websites and a public aquarium exhibit.

This research will address critical habitat concerns for right whales, provide information on baleen whales in context within the Bering Sea ecosystem, and illuminate ongoing or future research needs. This project also demonstrates aesthetic, emotional and educational value to students and their communities in the Bering Sea area, as well as to the general public via websites and outreach venues such as the Aquarium of the Pacific (Long Beach, CA).

Approach, Evaluation and Methodology

Eastern North Pacific right whales (hereafter referred to as 'right whales') are among the most endangered large cetaceans in the world. In recent years, right whales have been seen most frequently in the Bering Sea middle-shelf region (50- 100 m depth), despite a historical distribution that included the southeast Bering Sea shelf break and middle-shelf, eastern Aleutian Islands, and the entire Gulf of Alaska. Because sightings of right whales are rare, their abundance, distribution, and behavioral ecology in the Bering Sea are not well understood. Recent publications on large whale distributions and their relation to oceanography in the Bering Sea are based primarily on data from aerial or vessel-based visual surveys, which are 'snapshots' of whale distribution and conducted only in daylight, good weather, and summer months.

Research Accomplishments

Data collection
We deployed autonomous, bottom-mounted hydrophones to provide continuous, long-term data on distribution and behavior of calling whales in the southeast Bering Sea. To date, we have conducted a total of 13 such instrument deployments in the southeast Bering Sea yielding acoustic data (Table 1), with support from NOAA/NMML, NFWF, and ADFG. Eleven of the deployments were Acoustic Recording Packages (ARPs; Wiggins 2003), which sampled continuously at 500 Hz or 1000 Hz, recording an effective bandwidth encompassing that of fin whale calls, most right whale calls (McDonald and Moore 2002), and some humpback whale calls. Four High-frequency Acoustic Recording Packages (HARPs) were incorporated into NOAA/PMEL sub-surface moorings at sites M2 and M4 and sampled continuously at 80 kHz or 32 kHz, for an effective bandwidth to record killer whale and pinniped sounds in addition to baleen whale vocalizations. In addition, we used temporary, directional hydrophones (DIrectional Frequency Analysis and Recording (DIFAR) sonobuoys) to record right and fin whales (as well as other sounds up to about 4000 Hz) in the southeast Bering Sea in summers of 2002 and 2004, during NOAA AFSC, NMML, and SWFSC cetacean survey cruises. Other data collected during these surveys included photographs and video footage, observational data, and genetic data from biopsy samples.

In late September 2004, we recorded right whale calls during a NOAA vessel-based survey offshore Kodiak Island. The calling whales were not detected visually. Data analysis is underway.

Data processing
We processed data from 2000-2002 ARP deployments, using a combination of manual and automated call detection to find right whale calls. We used the software 'Ishmael', by David Mellinger, available online at http://cetus.pmel.noaa.gov/cgi-bin/getinfo.pl?dirname=ishmael, to cross-correlate the recorded sound spectrograms with a synthetic kernel based on the right whale 'up' call, the most commonly heard right whale call in the Bering Sea (McDonald and Moore, 2002). A recent publication (Munger et al. 2005, Appendix A) describes this automated call detection technique.

The spectrogram cross-correlator also detected calls from humpback whales in the same frequency band used by right whales. We used a Matlab-based program (Triton, Wiggins 2003), to view spectrograms of each detected call and identify to species by comparison with known characteristics of right whale and humpback whale calls. We also manually scanned recordings up to one day before and after automated detection events to find additional right whale calls missed by the detector.

Results
       A) right whale seasonality
The ARP recordings provide new information on the seasonal occurrence of right whales in the southeast Bering Sea. Right whale calls were detected as early as May in 2002, and through October and into early

November in both 2000 and 2001. A manuscript on right whale call seasonality is in preparation, pending the analysis of 2004-2005 data.

B) Localization

The acoustic environment in the southeast Bering Sea has enabled us to localize calling right whales at distances on the order of 10s to 100 km for ARPs and sonobuoys. We published a journal article on the use of normal-mode modeling to estimate range to calling right whales in the Bering Sea (Wiggins et al. 2004, Appendix B). A manuscript is in preparation on the use of DIFAR sonobuoys during vessel surveys to find right whales at long (50-100 km) detection ranges.

PAST DEPLOYMENTS

SEBS middle-shelf	HARP	32000, contin	09/27/04	56-51.614 N 164-03.652 W, 71m
SEBS middle-shelf	HARP	32000, contin	09/30/04	57-51.18 N 168-52.2 W, 70m

CURRENT DEPLOYMENTS

Bering shelf break	ARP	500, contin	04/29/05	54-0.0 N 170-0.0 W, 1870m
Bering shelf break	ARP	500, contin	04/30/05	55-54.065 N 169-52.007 W, 1590 m
SEBS middle-shelf	HARP	40000, contin	04/23/05	56-51.62 N 164-03.52 W, 72 m

Table 1. List of past and current Acoustic Recording Package deployments during the 2004-05 reporting period in the Bering Sea and Gulf of Alaska.

Paired Oceanographic Whale Call Samples

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Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management

Research Objectives and Specific Plans to Achieve Them

The NOAA National Marine Mammal Laboratory (NMML) has an on-going collaboration with the Scripps Institution of Oceanography (SIO)/Joint Institute of Marine Observations (JIMO) to conduct passive acoustic monitoring for right whales in the Bering Sea and odontocetes (toothed whales) off the coast of Washington. The objectives of this project are to collect and analyze data on right whale and odontocete calls as a step toward modeling cetacean presence over broad temporal and spatial scales, and for incorporation into ecosystem models.

Approach, Evaluation and Methodology

The present project used DIFAR sonobuoys to locate and track right whales in the Bering Sea, and serviced two High-frequency Acoustic Recording PackageS (HARPS) offshore from Washington to augment and extend the acoustic data time series in that area. These instruments sample at 80 KHz (40 KHz maximum frequency) to provide data on odontocete calls.

Research Accomplishments

During the summer/fall of 2004 SIO Specialist Allan Sauter and Graduate Student Lisa Munger participated in a NMML/AFSC expedition to the Bering Sea. They conducted studies of right whales with sonobuoys and were

able to help the expedition in locating right whales for more detailed studies. In addition, two HARPS were deployed during July 2004 using the University of Washington research vessel *Centennial*. The work was performed in accordance with permit OCNMS-2004-004. One of these instruments was serviced during October 2004 and again in July 2005 and these data are currently being analyzed for odontocete calls.

Measurement and Modeling Analysis of Organic Aerosol and Their Cloud Interactions

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Links to NOAA Strategic Plan:
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Research Objectives and Specific Plans to Achieve Them

After sulfates, organic compounds are the most abundant component of fine aerosol globally. Some estimates show that organic compounds comprise 10-50% of the mass of fine aerosol. The plethora of organic compounds in the atmosphere span a wide range of chemical, thermodynamic, and optical properties, none of which is known sufficiently well for global climate models. Understanding the optical and hygroscopic properties of organic aerosols is essential to quantifying their effect on climate.

Approach, Evaluation and Methodology

In this project, we are collecting and analyzing organic samples as part of two NOAA field projects, NEAQS/ITCT (New England Air Quality Study/Intercontinental Transport and Chemical Transformation) 2004 and the Atmospheric Brown Cloud (ABC) experiment. In both NEAQS/ITCT and ABC, organic functional groups and mass from FTIR analysis of filters will be compared to concurrent inorganic chemical and extinction, scattering, and absorption coefficient measurements. These measurements will complement the existing NOAA measurements by (1) quantifying the amount and types of organic compounds and (2) assessing the microphysical and optical roles of these organic particles in cloud. The measured organic composition will be analyzed using state-of-the-art microphysical, thermodynamic, optical, and radiative transfer models. Much of this work will contribute to our ongoing collaboration on aerosol-cloud-climate interactions with NOAA GFDL investigators (Erlick et al., 2001; Garrett et al., 2003; Randles et al., 2004; Ming et al., 2005; Erlick et al., 2005).

Research Accomplishments

Organic measurements on the *R/V Ron Brown* and at Chebogue Point in 2004 are being carried out to provide essential data on organic chemical composition to complement the existing suite of NOAA measurements. These measurements are valuable because they provide more chemical bond information than is provided by the NOAA EGA, particle into liquid sampling (PILS), and AMS measurements. The strengths of the FTIR approach are that it provides more accuracy for total organic than EGA, more complete analysis of a larger fraction of water-soluble organic compounds (WSOC) than PILS, and more specific chemical function information than AMS. The latter FTIR measurement of chemical functionality provides a critical characterization of water uptake, reactivity, and absorption for the organic fraction. Because of this chemical bond information, the FTIR measurements enable the chemically specific modeling of the measured organic composition providing an important part of optical closure studies that we have contributed to past NOAA studies (Quinn et al., 2004).

The FTIR technique has higher accuracy than other measurements of total organic carbon (Russell, 2003). The samples use Teflon filters and duplicate blanks to minimize sampling artifacts and reduce the detection limit. A 1-μm particle diameter cyclone will be used to remove larger particles from the sample stream that might bias the composition. The resulting submicron organic mass and functional group composition measurements will provide organic mass estimates with less than 20% uncertainty (compared to 70% uncertainty that is typical of real-time EGA).

For this project we have started FTIR and XRF analyses for elemental and organic composition of samples collected as part of NEAQS/ITCT 2004 studies, including:

a. Samples collected on board the NOAA *R/V Ron Brown*, synchronized with complementary measurements by Sunset EGA, PILS-TOC, Aerodyne AMS, PILS-LCMS, IC, cavity-ring down, nephelometer, soot absorption photometers, and other instrumentation by NOAA collaborators (including T. Bates, P. Quinn).

b. Samples collected at Chebogue Point, with timing coordinated to AMS and other NOAA measurements of chemical composition (D. Worsnop, D. Parrish).

Results to date:

Alkanes, alkenes, aromatic compounds, ammonia, nitrates, sulfates, organo-sulfur compounds, carbonyl and oxydril functional groups were detected by FTIR spectroscopy in atmospheric aerosol samples collected at Chebogue Point in Nova Scotia and aboard the *R/V Ron Brown*. Examples of FTIR spectra from each site are shown in Figures 1 and 2.

Saturated and unsaturated hydrocarbons show a fairly constant ratio on the *R/V Ron Brown*, with more variability and a stronger contribution from saturated compounds at Chebogue Point. The *R/V Ron Brown* samples also showed more carboxylic functional groups than the Chebogue Point data set.
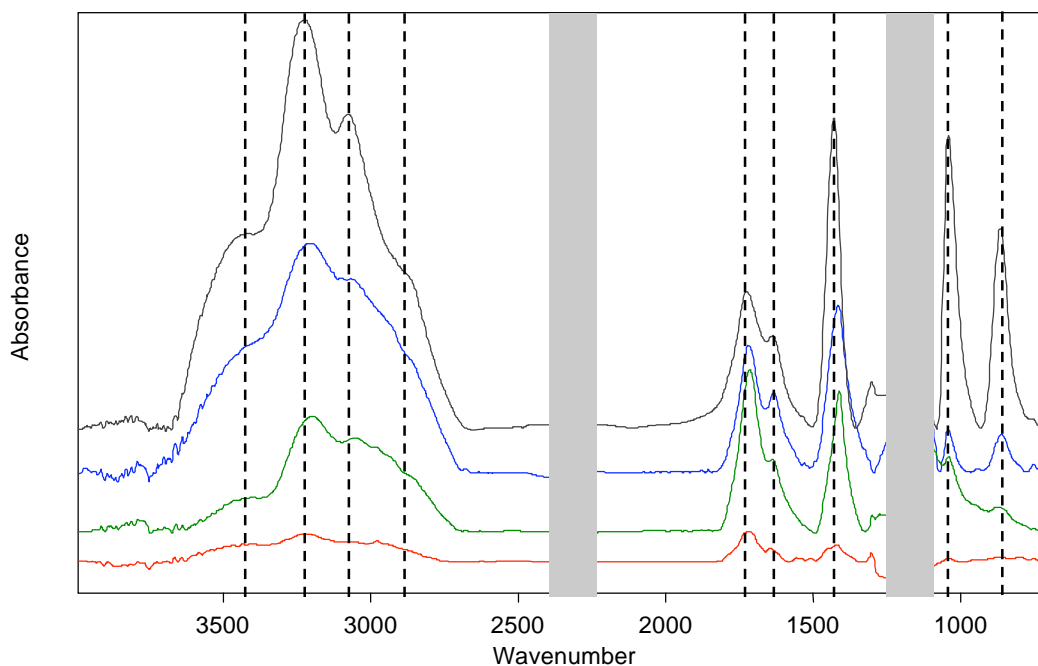
Fig.1 Fourier Transform Infrared (FTIR) spectra of some representative atmospheric aerosol samples collected during Ronald H. Brown cruise. CO2 and Teflon absorption regions have been removed (gray areas). Identified functional groups are indicated by a dotted line and include hydroxyl group (3500 cm-1), ammonium (3200 cm1 and 1430 cm-1), alkene and aromatic (3000-3100 cm-1), alkane (2850-3000 cm-1), carbonyl group (1680-1700 cm-1), water (1640 cm-1), sulfate (1100 cm-1) and organosulfur compounds (875 cm-1).

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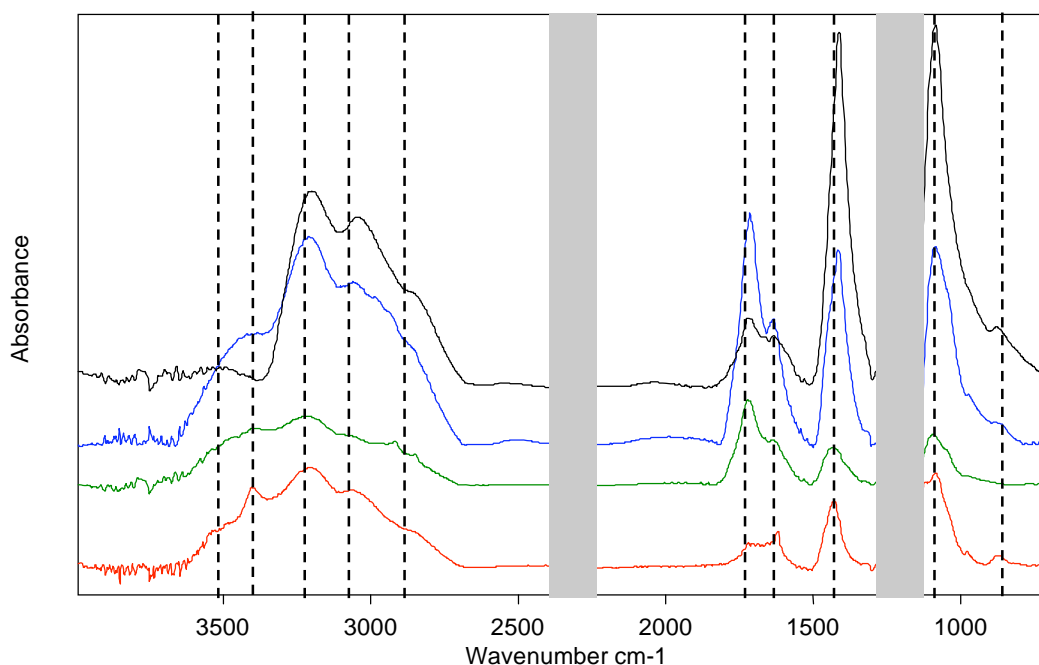
Fig. 2   FTIR spectra of some representative atmospheric aerosol samples collected in Nova Scotia. CO2 and Teflon absorption regions have been removed (gray areas). Identified functional groups are indicated by a dotted line and include hydroxyl group (3500 cm-1), ammine (3400 cm-1 and 1620 cm-1), ammonium (3200 cm1 and 1430 cm-1), alkene and aromatic (3000-3100 cm-1), alkane (2850-3000 cm-1), carbonyl group (1680-1700 cm-1), water (1640 cm-1), sulfate (1100 cm-1) and organosulfur compounds (875 cm-1).

Exploring Vailulu'u Seamount: Bio-, Hydro-, and Lithosphere Interactions

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Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management

Research Objectives and Specific Plans to Achieve Them

Task 1 Document the volcanological setting and survey for hydrothermal vents.
Task 2 Characterize the water-column properties through CTD and Niskin Bottle sampling from Pisces and hydrocasts.
Task 3 Deploy current meters, temperature probes and recording LBSS, either by shipboard deployment and retrieval or by targeted deployment by submersible (e.g. a Falmouth Scientific Instruments Acoustic Doppler current meter) in the crater breaches and summit.
Task 4 Exposure experiments: deploy a set of synthetic oxidized and reduced basaltic glasses in various forms, as polished sections, for studying surface colonization and hydration rind thickness.
Task 5 Sample glassy margins, biofilms, volcaniclastics and microbial mats in different hydrothermal regimes and eruption exposure ages.
Task 6 Sample organisms for morphological and reproductive studies.
Task 7 Determine the effects of pulsed-water events on microbial and benthic communities.

Approach, Evaluation and Methodology

Two cruises aboard the Kaimikai O' Kanaloa were carried out during a four day cruise in March - April and an 9 day cruise in June/July including a total of 12 scientists: H. Staudigel (chief scientist); Brad Bailey, Sandra Brooke, Stan Hart, Lisa Haucke, Ian Hudson, Ray Lee, Adele Pile, Brad Tebo, Alexis Templeton and on the second cruise we also included Richard Smith from the Australian Broadcasting Company. These dives were devoted to the exploration of the hydrothermal and biological systems of Vailulu'u and the deployment and retrieval of exposure experiments, current meters and temperature and light backscattering recorders.

Research Accomplishments

Nafanua, a new submarine volcano on Vailulu'u Seamount erupted within the last four years, rising from the 1000m deep crater floor to form a new central summit with a depth of 708m. This depth is well above the two major breaches in the crater wall and continued growth could bring the summit close to the sea-surface within a decade, even though there is currently no evidence of active lava flows.

Vailulu'u and its newest pillow volcano Nafanua produce substantial amounts of hydrothermal fluids and particulates that decrease visibility inside most of the crater to 2-10 meters and locally cause near bottom water pH as low as 5.1. LBSS data suggest that the highest particulate are found at water depths > 740m (consistently above 0.4 NTUs) whereby similarly high turbidities may be found as shallow as 680m (always lower than 0.3 NTU's), with highly variable turbidities in between (0.05-.4 NTU's). The sources of hydrothermal particulates are not clearly understood, but submersible observations identified three distinct hydrothermal vent complexes inside the crater. All of these vent complexes are located in a linear array that coincides with epicenter clusters of volcano-tectonic earthquakes that occurred in April-June 2000. (1) The highest temperature vents (up to 85°C) were found at the foot of the northern crater wall forming a diffuse zone of venting in several nearby, 10m-sized fields. Low salinities in the hydrothermal fluids suggest that they were formed originally as steam in a boiling reaction zone that subsequently condensed, mixed with other waters and vented. Some of these high temperature fields vent substantial quantities of rising drops of an oil-like liquid, most likely CO_2, that could play a role in generating the acidity of crater waters in this region. This vent field formed in a portion of the crater that is older than Nafanua and might probably pre-date its formation. (2) A major, low temperature vent field was found on the summit of Nafanua with diffuse venting of hydrothermal waters at temperatures a few degrees above ambient temperatures. Nafanua low T vent fields are best recognized by the common occurrence of 2-4 cm thick microbial mats, that can exceed thicknesses of a meter in some protected areas. Nafanua summit vents may be fed from a weak deep rooted hydrothermal source or represent the final stages of cooling of this newly emplaced volcano. (3) Another type of low temperature vents (ambient to about 28°C) produce cm to meter-sized Fe- oxide chimneys. The largest field is located on the inner South crater wall. Both low T hydrothermal vent types were also found on the west rift of Nafanua.

Methane Seeps Under Hypoxia: Novel Ecosystems within Eastern Pacific Oxygen Minimum Zones

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Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management

Research Objectives and Specific Plans to Achieve Them

Unusual and novel ecosystems in the deep sea are often found where environmental stressors combine to create unique conditions. This project is intended to explore the benthic communities that develop where methane seepage and attendant high sulfide concentrations intersect with the natural hypoxia associated with global oxygen minimum zones (OMZs). Our specific targets are in the Gulf of California and off Peru. These are to be studied by utilizing Mexican and Peruvian research vessels with a combination of ship-based sonar, video imaging by Phantom ROV, multicoring, trawling and dredging. Our objectives are to (a) locate and survey novel seep ecosystems within OMZs, establishing their geologic and hydrographic setting, (b) document the distribution of reducing communities in relation to geological surroundings, (c) quantify the abundance and composition of biotic assemblages, (d) establish the nature, distribution, and biological effects of hydrocarbon-generated crusts and condensates around the seeps, (e) evaluate the influence of low oxygen on the biogeography, diversity, metabolic and trophic pathways represented, and (f) draw comparisons to better oxygenated seep ecosystems and to OMZ ecosystems without seepage. We anticipate that this research will advance understanding of biotic response to hyper-stressed conditions (sulfide toxicity and hypoxia), expand known biogeography of reducing ecosystems, and yield insight into evolution within ultra-extreme environments. For our group these studies will broaden our understanding of seeps as unusual environments, expand our views of marine biodiversity and contribute much needed biogeographic data for Eastern Central Pacific deep-sea ecosystems. Major foreign partners are Elva Escobar, Universidad Nacional Autonoma de Mexico (UNAM, Mexico), and Dimitri Gutierrez (IMARPE, Peru). Major US partners are Wiebke Ziebis (University of Southern California) and Anthony Rathburn (Indiana State University). Primary activities involve 2 research cruises in 2005, one in May 2005 in the Gulf of California and one off Peru in Dec. 2005. These involve imaging and sampling of biota on the seabed in search of low oxygen areas with methane seepage.

Approach, Evaluation and Methodology

To date, we have competed one cruise, aboard the *R/V El Puma* in the Gulf of California (May 19-28). Cruise objectives were to: (1) locate and survey novel seep ecosystems within OMZs in the Gulf of California and off Mazatlan, and (2) characterize the habitat and organisms of these ecosystems. We wished to evaluate the influence of low oxygen on the evolution, biogeography, diversity, metabolic and trophic pathways of organisms in these ecosystems. Measurements and sampling at sea included CTD profiling of temperature and salinity, winker analysis of oxygen from water samples collected by rosette, echo sounding, multicoring, dredging and digital still photography.

Research Accomplishments and Results

This project began in February 2005 and by the time of this report was less than half completed. Another cruise is planned for the coming year. On the first cruise, no methane seeps were located. However, a variety of unusual low oxygen systems were explored. Key findings include the following:

(1) A sulfidic basin containing sediments composed largely of diatomaceous phytodetritus at San Pedro Matir (860 m). Sediments were highly sulfidic and supported filamentous sulfur bacteria but few metazoan animals.
(2) A rocky ridge at San Pedro Matir supporting large numbers of small sharks, shrimp, crabs and sponges at its base. This appears to resemble the dense megafaunal aggregations found at lower OMZ boundaries in other regions.
(3) A trough at the base of the San Pedro Matir ridge with a series of bumps and hills (evident on the echo sounder) characteristic of gas emission.
(4) A plankton layer that migrates into the upper OMZ during the daytime, forming a dense layer at 300-400 m. We believe this may be comprised in part of jellyfish.
(5) A diverse 'deep water' assemblage at Las Animas Basin" (1440 m) comprised mainly of agglutinated protozoans and tube building polychaetes (chaetopterid, trichobranchid, maldanid and onuphid), with tubes penetrating 50-75 cm into the sediment. No evidence of vent or seep fauna was found.
(6) The OMZ on the Mazatlan margin contained fine, soupy sediments with large amounts of woody debris. Annelids were abundant (cirratulids, paraonids, trichobranchids, cossurids) as were sulfur bacteria and large agglutinating protozoans (mud walled astrorhizinids).
(7) Novel adaptation of an inexpensive deep-sea, digital drop camera for towed use.

We encountered difficulties with gear importation/exportation between the US and Mexico. Some of this prevented importation of the ROV and we resorted to use of a digital drop/towed camera. This was not fully functional until the end of the cruise. There were also problems with navigation and accurate placement of instruments–making location and sampling of small-scale seep sites difficult.

On the positive side, outreach activities included a multinational, multilingual expedition involving a broad range of scientists, nationalities, disciplines and levels of expertise (from undergraduate and graduate students to senior scientists). There was technology transfer (camera system and quick release technology) across institutions. New collaborations were formed and students had the opportunity to bond across institutions and countries.

Samples have yet to be imported from Mexico to the USA, so we have few concrete results to report. We can however comment that a wealth of opportunity exists for studies of hypoxia in the Gulf of California and off the Pacific coast of Mexico. A tantalizing collection of very small juvenile vesicomyid clams on hardground near San Pedro Matir Ridge suggests that the seeps of interest are probably still out there waiting to be discovered.

Fig. 1 Mazatlan margin, oxygen min. zone: 750 m.

Fig. 2 Agglutinated protozoans dominate the fauna at 1440 m in Las Animas Basin, Gulf of California.

Joint Project Agreement Concerning the National Spatial Reference System in California

Yehuda Bock (SIO)

NOAA Technical Contact: Gilbert Mitchell (NGS)
Links to NOAA Strategic Plan:
NOAA Goal 4: Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation

Research Objectives and Specific Plans to Achieve Them

NOAA's National Geodetic Survey (NGS) and the California Spatial Reference Center (CSRC) have joined in partnership for the purpose of researching spatial referencing and height modernization for the public good. Although focused on California, our goal is that our research will contribute directly to the development by the NGS of public guidelines and procedures for other states and entities interested in implementing height modernization and spatial reference systems. The specific objectives of the project are to research and implement the scientific and infrastructure basis for the California Spatial Reference System. There are several outstanding research questions related to spatial referencing that are being addressed, for example:

1. What is the proper observation mix to maintain a modern height network, and how should these measurements be optimally combined? Observation types include continuous GPS (CGPS) including real-time high-rate networks, field GPS surveys at passive monuments, leveling, and gravity surveys.
2. What analysis procedures should be applied to these observations, and in what reference frame should they be expressed in, recognizing that California is subject to crustal deformation due to plate tectonic, volcanism, and hydrological effects.
3. What is the proper mix of geoid models and local corrector surfaces, in converting from GPS-determined geodetic heights to orthometric heights? What interpolation methods will provide the optimal corrector surfaces?
4. Can we apply and enhance modern IT methods to provide timely access to height modernization information?
5. How does one develop and implement a precise GIS for the purposes of height modernization?

The CSRC has been established to achieve the above research objectives. The R&D and operational arm of the center is located at Scripps, and leverages the resources of the Scripps Orbit and Permanent Array Center. The CSRC also consists of an Executive Committee, Coordinating Council, and a user community, organized as a UCSD Support Group. Along with our sponsors at NGS, the Exec. Committee provides advice on the research direction, the relevant civil applications, and the allocation of resources. The overall success and management of the project is the responsibility of the PI.

Approach, Evaluation and Methodology

The development and implementation of the CSRS will follow these general guidelines:
(1) GPS (and in the future complementary GNSS systems such as Galileo) will provide the CSRS backbone of precise, time-varying coordinates of hundreds of permanent (active) stations in the State.
(2) The underlying reference frame will coincide with the International Terrestrial Reference Frame (currently ITRF2000) or future incarnations adopted by recognized international organizations (IERS, IGS). All GPS analysis and network adjustments will be performed with respect to this frame.

(3) Transformations to national horizontal and vertical datums (e.g., NAD83. NAVD88) after adjustment in ITRF will be performed through jointly (CSRC and NGS) approved transformation and model parameters.

(4) The time-varying nature of coordinates in California will be incorporated into the CSRS. Corrections (e.g., velocities, offsets) will be provided through jointly approved models (SECTOR/HTDP) to allow the user to compute consistent coordinates at any observation epoch.

(5) National geoid models will be the basis of converting ellipsoidal to orthometric heights. Local adjustments will be applied as needed.

(6) The CSRS will maintain a seamless, integrated network so that all corrections (to horizontal or vertical coordinate components) are traceable to a reference epoch. Changes to the reference epoch will be minimized. However, updates to correction models need to be part of an ongoing and timely process, in concert with the scientific community and NGS.

The project is being carried out with a mix of SOPAC/CSRC staff at Scripps, geodetic consultants, private contractors, and CSRC volunteers. SOPAC/CSRC staff and geodetic consultants focus on the research questions and developing the IT infrastructure. The geodetic consultants are involved in data analysis, project supervision, education, and public outreach. Private contractors perform geodetic measurements (leveling and GPS) in support of the CSRC Master Plan.

Research Accomplishments

To address the research objectives outlined above we have collected, analyzed, and interpreted data in the San Joaquin Valley and neighboring regions, in support of CSRC's "A Master Plan for a Modern California Geodetic Control Network." In Northern California the availability of NAVD88 benchmarks is limited and we worked with Caltrans on a project to establish 900 passive stations in Caltrans North Region. The SJV project (Figure 1) encompassed the entire San Joaquin Valley of California, from Modesto in the North to Bakersfield in the South (totaling about 62,000 square miles). The private contract for this project was awarded to Condor Earth Technologies in May of 2004. In addition to the extensive network observed by Condor, the California Department of Transportation (Caltrans) contributed 3 GPS subnetworks attached to the overall scope of the network–one project near Los Banos, another near Visalia, and an earthquake study in the vicinity of San Luis Obispo, which has been carried out to estimate the displacements resulting from the San Simeon earthquake in late December of 2003. In addition to the GPS networks, Caltrans ran more than two hundred kilometers of precise leveling across the valley floor. The active geology of this survey includes not only the San Simeon earthquake, but also vertical subsidence of more than a meter over a period of 12 years in the floor of the valley along both Route 152 and Route 198. A report documents this project (see references).

In order to facilitate a streamlined and efficient exchange of information during height modernization and geodetic densification performed by the CSRC, we have developed a Web Services based infrastructure of client applications and centralized information servers using SOPAC. One of our major accomplishments this year is the development of version 1.0 of the Pocket GPS Manager (PGM)–a wireless PDA application designed to eliminate the use of paper GPS field logs via direct communication with a set of centralized information services using modern information technologies through a variety of network transport mechanisms (Figure 2). This development was specifically requisitioned by NGS as one that was applicable to the overall national height modernization program, not just the CSRC. PGM was developed to fit seamlessly with SOPAC/CSRC's Web Services based infrastructure of client applications and centralized information servers, and to support ongoing height modernization and geodetic densification projects that are part of the implementation of the CSRC's Master Plan. PGM was also designed to integrate with the session-mode GPS processing that is required for these projects, as components of the California Spatial Reference System (CSRS).

The CGPS sites from the existing regional networks in the western U.S. are transitioning to UNAVCO's Plate Boundary Observatory (PBO), with full transition, except for about 125 SCIGN sites, to be accomplished by 2008. This will have significant impact on CSRC since maintenance of these existing sites will be secured though the EarthScope/PBO funding. In addition, PBO will establish several hundred new CGPS sites in California, which will need to be integrated into the California Spatial Reference System by computing coordinate time series for these new sites. CSRC personnel are working with PBO regional engineers in southern and northern California, in order to meet the objectives of PBO and CSRC. We have also continued to upgrade CGPS stations to real-time high-rate operations in San Diego, Imperial and Riverside counties.
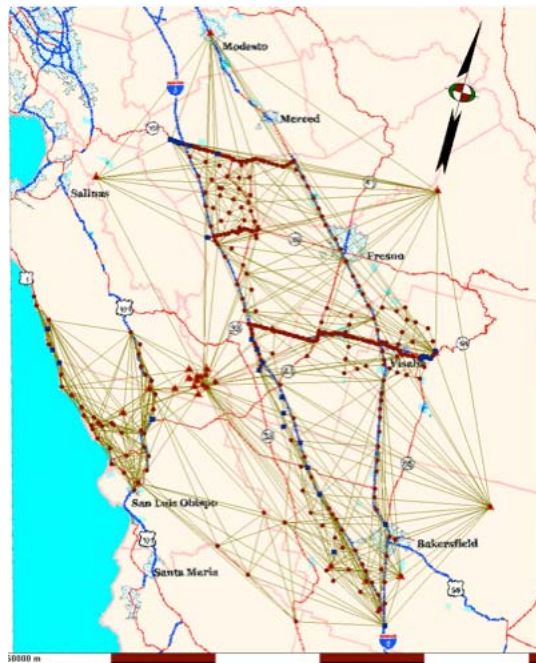
Fig. 1 Map of the San Joaquin Valley height modernization project. It encompassed the entire San Joaquin Valley of California, from Modesto in the North to Bakersfield in the South (totaling about 62,000 square miles). The California Department of Transportation (Caltrans) contributed 3 GPS subnetworks attached to the overall scope of the network—one project near Los Banos, another near Visalia, and an earthquake study in the vicinity of San Luis Obispo, which has been carried out to estimate the displacements resulting from the San Simeon earthquake in late December of 2003.
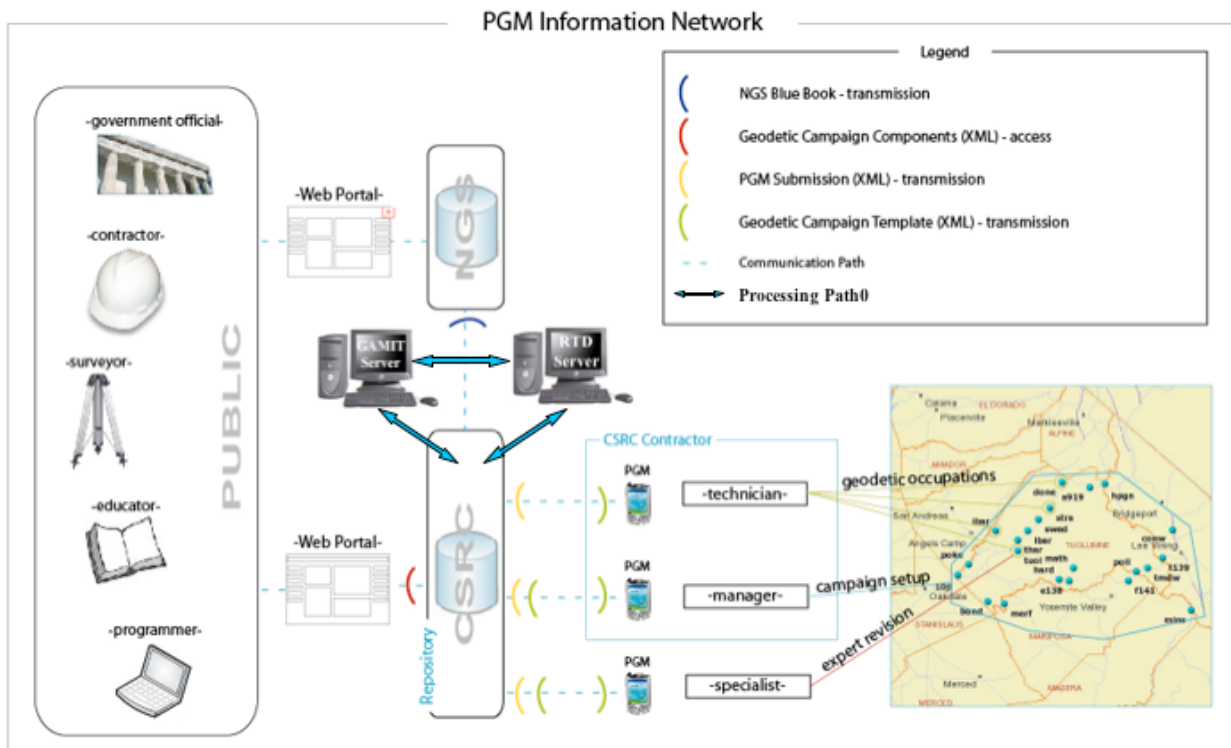
Fig. 2 Schematic of version 1.0 of the Pocket GPS Manager (PGM)–a wireless PDA application designed to eliminate the use of paper GPS field logs via direct communication with a set of centralized information services using modern information technologies through a variety of network transport mechanisms.

Implementation of a Real-Time Precipitable Water Capability Using the Global Positioning System

Yehuda Bock and Peng Fang (SIO)

NOAA Technical Contact: Seth Gutman (FSL)
Links to NOAA Strategic Plan:
NOAA Goal 4: Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation

Research Objectives and Specific Plans to Achieve Them

To realize the goal of estimating precise (≤ 1.5 mm RMS) integrated precipitable water (IPW) within 2 hours using a network of continuous GPS receivers distributed over the continental U.S. as a way of supplementing and improving numerical weather prediction models, i.e., short-term weather forecasting. At NOAA's Forecast Systems Laboratory (FSL), a ground-based GPS meteorology system has been implemented, with continued scientific input, oversight and refinement from the Scripps Orbit and Permanent Array Center (SOPAC). One of the breakthroughs in the system is the ability to generate quality-controlled, hourly orbital estimates for the GPS satellites at SOPAC, using a 48-hour sliding window in hourly increments. The precision of the orbits is about 7 cm within the observed session and below 15 cm in the predicted 12-hour segment.

Approach, Evaluation and Methodology

We have evaluated approaches to provide more robust and timely GPS satellite orbits. These include using longer orbital arcs, introducing more even spatial coverage of data from global GPS tracking stations, and developing redundant and more robust quality control mechanisms. We have also evaluated new methodologies to reduce the latency of derived GPS zenith delays from single-epoch instantaneously estimated zenith delay parameters.

The co-PI (P. Fang) interacted closely with our sponsor at FSL (Seth Gutman and his staff) to enhance the FSL system. The PI (Y. Bock) worked with the sponsor to evaluate the instantaneous zenith delay estimation approach.

Research Accomplishments

High quality orbits are now delivered hourly with better than 98.4% (6 interruptions over a 366 day period, most of them due to network system related problems) reliability with a precision of about 7 cm, and a predictive capability of 15 cm. A redundant processing system has been implemented to improve the reliability of GPS orbit support at SOPAC for NOAA. An instantaneous tropospheric delay estimation system using a dense continuous GPS network in southern California has been shown to provide useful information for GPS meteorology.

Participation in IT Infrastructure for the Future Study Group

James J. Simpson (SIO)

NOAA Technical Contact: Alfred Powell (NESDIS)
Links to NOAA Strategic Plan:
NOAA Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through an Ecosystem Approach to Management
NOAA Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
NOAA Goal 3: Serve Society's Needs for Weather and Water Information
NOAA Goal 4: Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation

Research Objectives and Specific Plans to Achieve Them

This study supports the NOAA's National Environmental Satellite, Data, and Information Services' (NESDIS) strategic goals by helping to realize the full potential of current and future satellite data by: 1) Shortening the cycle times from research to operations through the use of test beds and other methods; and 2) Increasing capabilities of data acquisition technology, processing, and analysis capabilities.

Approach, Evaluation and Methodology

The underlying principles of modularity, encapsulation, and controlled interfaces are fundamental to good design regardless of system topology. Observing those precepts and understanding and documenting the requirements of the future ORA system led team members to quality solutions independent of specific architecture or clustering technique.
The Study Group also reviewed several functional systems (e.g., the PIPE system developed at DIAL and described in Fig. 1 is one example of the systems studied) which support activities similar to those of ORA. There was strong similarity in the underlying design of the successful systems evaluated. Although implemented very differently and on different computational architectures, they followed the same basic tenets of good system engineering. In each case design principles were not inferred after the fact, rather the principles were front and center as these systems were being built by their respective developers.

Research Accomplishments

Parallel Image Processing Environment (PIPE): This system, courtesy of Dr. James Simpson, of the Scripps Institution of Oceanography's Digital Image Analysis Laboratory (DIAL), is an example of one of the successful and fully functional systems evaluated within the context of ORA's future needs. It was implemented in a highly structured environment over which he has considerable control. An array of identical servers, controlled by a head node, runs each job and allocates resources to it. I/O is buffered and translators are provided (and gradually supplemented over time) to handle incoming data and map it into an internal structure that is recognized by the software. Agents or daemons handle the allocation of resources, errors, and post-run tidy-up. User algorithms are embedded in a structured way into the software. The framework or middleware software manages resources and supplies capabilities in a predictable manner to the user algorithms. Statistics on algorithm resource use and bottlenecks are a feature of the system and can be used to tune algorithm performance and balance loads so that, for example, processors do not sit idle while waiting for data. Figure 1 describes the abstraction that underlies PIPE. Primary languages are C and Perl and to a much lesser extent Fortran. Fortran is, however, fully supported.

PIPE provides extensible library support for image analyses, satellite-data analyses (sensor general/sensor specific), and geophysical applications. Each application is abstracted as a generalized filter in a streaming paradigm. Multiple streams allow ancillary data to be incorporated into the flow as needed by a given application. New applications require relatively little time to build/test because each new application is "decomposed" into its component parts of sub-filters as part of the new application abstraction and design process. Generally, most of the component filters already exist in PIPE's application support libraries. Any new

filter needed by a new application is also incorporated into PIPE's application support libraries. Maximum reuse of software is achieved with this approach to new application design and implementation. A detailed description of PIPE is available by FTP at ftp://dial.ucsd.edu/pub/outgoing/PIPE/.
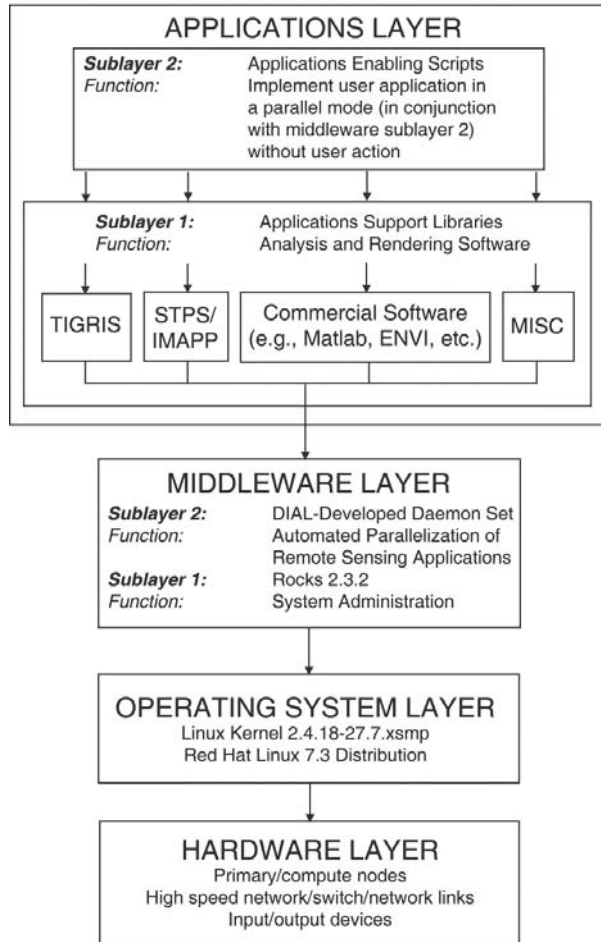

Figure 1. PIPE Cluster Architecture. PIPE provides distinct layering of the various system functions. This improves the ease of extensibility or upgrade of any component because its interactions with other components are controlled. (From Simpson et al., 2005)

DO, TDS, SALINITY, AND OTHER TESTS ON THE SAN DIEGUITO RIVER

HABITATS STUDIED   METHODS

SITE A

RESULTS

OUTREACH

SCOPE

SCOPE, Scripps Community Outreach and Public Education, is an organization of graduate students, faculty and staff at SIO who have come together to identify, as well as create, E&O opportunities for SCOPE members. Students working in JIMO funded labs have participated in a variety of SCOPE sponsored outreach activities including helping with K-12 curriculum review, staff briefings and assistance with program planning with many science education organizations external to SIO. Lisa Munger (J. Hildebrand) is now 1 of 3 SIO grad students leading the organization.

Exhibit Advisors at BAS

The mission of the Birch Aquarium at Scripps is threefold: [1] To provide ocean science education through creative exhibits and programs designed to help people use critical thinking and to make science relevant to their daily lives; [2] To interpret Scripps Institution of Oceanography research, emphasizing the interdisciplinary nature of the sciences used to study Earth and inspire public support of scientific endeavors; [3] To promote conservation through education and research, believing that with increased understanding of the oceans, people will respect and protect the marine environment.

BAS hosts more than 360,000 visitors per year, including many K-12 and college students. JIMO scientist Chris Charles is currently serving as an exhibit advisor on an upcoming exhibit on global change (opening Fall 2007). Chris will provide material and intellectual resources and review exhibit components for scientific accuracy prior to fabrication phase.

COSMOS

http://www.jacobsschool.ucsd.edu/cosmos/

COSMOS (http://www.ucop.edu/cosmos/) is the California Summer School in Math and Science–a program designed to encourage and inspire bright high school students to pursue an academic career in Math, Science or Engineering. The program, which has been running for several years at three UC campuses (Davis, Irvine and Santa Cruz; see examples of courses taught in attached file) will start at UCSD in summer 2005. The program provides a 4-week residential experience at UCSD for high achieving high school students. Clusters of courses are offered in a variety of disciplines taught by UC faculty or researchers. SIO is a major participant in COSMOS. Andrew Dickson and Tim Leuker (Ralph Keeling lab) are teaching a course cluster focused on Global Change.

University Extension Teacher Professional Development

The UCSD Extension program offers summer teacher professional development workshops on marine geology and biological oceanography for local area K-12 teachers. The week-long workshops include presentations and hands-on demonstrations by researchers from SIO. Peter Franks' lab participates in this SIO-wide event.

TRIO Upward Bound Math & Science Program

TRIO is a UCSD Office of Student Educational Advancement project. (http://trio.ucsd.edu/). The Upward Bound Math & Science Program (UBMS) serves 44 high school participants in their preparation for college admission. This program works specifically with students who have an interest in pursuing math, science, computer science and engineering as a college major and career. UBMS tailors its outreach activities to address these interests, including providing a comprehensive summer residential experience each year at UCSD focused on these pursuits. SIO created a half-day fieldtrip experience for UBMS students called Discover Oceanography, an activity designed for 30-45 in middle or high school. Students rotate through 3 stations on the SIO campus and participate in hands-on activities that reflect ongoing research activities at SIO. Each station is run by 2 or more SIO graduate students. There is a similar program scheduled for the future which will include grad students from JIMO fellow labs, like the Hildebrand cetacean acoustics lab.

MARE

MARE (Marine Activities, Resources and Education) is a whole-school immersion program that helps elementary and middle schools nationwide to implement an intensive, school-wide marine science curriculum. The program provides a comprehensive curriculum for grades K-8 along with professional development and consulting for teachers, school administrators and parent leaders. Scripps/Birch is now a MARE Regional Center and is working with several schools in the area. Several graduate students have given presentations to students as part of school's month-long focus on the oceans.

Perspectives on Ocean Sciences Lecture Series: http://www.aquarium.ucsd.edu/public/persp_online.cfm
The Birch Aquarium at Scripps Perspectives on Ocean Science lecture series is a monthly event designed to inform the general public about research activities at SIO. Researchers create engaging, accessible presentations that typically draw more than 100 guests. Each lecture is filmed and edited by UCSD-TV for broadcast via UCSD-TV, UC-TV and a number of cable channels nationwide, reaching a potential audience of more than 5 million viewers. Each presentation is digitized and can be viewed online via the UCSD-TV and Birch websites. Nine JIMO fellows (Cayan, Charles, Franks, Hildebrand, Knox, Orcutt, Rudnick, Levin & Terrill) have made presentations in this highly successful and far-reaching program.

Kids-Can-Do

Kids-Can-DO is a national coalition of children involved in finding solutions for long-term problems they will other wise inherit as adults, including global change, habitat destruction and pollution. http://www.kids-can-do.org/
Ralph Keeling's work in global change research was recognized in a small ceremony at SIO. Ralph answered students' questions regarding global climate change and gratefully accepted the award.

NOAA Teacher at Sea

Using the HiSeasNet installation on the *R/V Revelle*, Bob Knox facilitated ship-to-shore video conferencing between NOAA Teacher at Sea Debra Brice (San Diego County teacher of the year) and a San Marcos high school classroom on shore. This provided a classroom of 9th grade geography students a real-time broadcast with the *Revelle* during Bob Weller's (WHOI) recent NOAA-funded cruise in Nov. 2004. This effort has proved to be the springboard for even more high quality video teleconferencing between ship and shore for educational purposes.

Email excerpt:

We cannot thank you enough for that fabulous day! Both the visualization center and MarFac were a phenomenal close to a great week for these students. They were talking about the ships all last evening at the parent night!

SIO Facilities Tours
In both 2004 (Bob Knox, Marine Facility ("MarFac") tour) and 2005 (Kevin Hardy of Hildebrand's lab, SIO pier activities), JIMO has supported local field trips to SIO and SIO facilities in support of this exemplary program. Students learn about Oceanographic research in general and the research conducted at SIO in particular.

SCCOOS (PIs: J. Orcutt, R. Davis, E. Terrill) Education and Outreach program
SCCOOS Education centerpiece is an eight-week Weather and Ocean Monitoring Program under development by the Ocean Institute (Sea Tech). Web components to support the program are under development at SIO. The eight-week program is being designed to meet 5th grade Earth Science standards on the water cycle and weather; it will include new classroom activities, science kits, CD-ROMs, web-based materials, field trips, teacher professional development and will incorporate SCCOOS science and scientists as a link to research being done in the field. Curriculum development for this program will occur over a three-year period, and will include teacher focus groups and training sessions in order to develop a program that effectively helps prepare students for California science standards and rigorous new assessments. Conservatively, the program will be piloted with approximately 500 students in three school districts. The program is being developed, however, to serve the needs of Orange County's 26 districts and will be disseminated through teacher professional development workshops. There is the potential to serve approximately 15,000 students this next year. Above: Students participating in the SeaTech program.

TeacherTECH at San Diego Supercomputer Center
Middle and high school science teachers participate in the SDSC monthly TeacherTECH Science Series. An engineer and a graduate student from John Hildebrand's group gave a presentation this past spring focusing on Marine Mammals and Sound in the Sea. Participants learned how to assemble a low cost hydrophone from easily available components.

Sounds in the Sea Interactive Display - Long Beach Aquarium of the Pacific
Dr. John Hildebrand's group developed an interactive display "SOUNDS IN THE SEA" at the Long Beach Aquarium of the Pacific, with a grant from Pacific Life. The exhibit won the American Association of Museums Silver Muse Award for 2005.

UCSD School of Engineering Undergraduate Program
JIMO proposed five senior projects to the UCSD School of Engineering. Two of the projects were selected, one given to an undergraduate team and the other to a graduate team. The undergraduate project involves the design of a deep-sea vehicle to deploy seismic sensors on the seafloor (shown to the left). The graduate student project involved the design, deployment and recovery of small, submerged buoys used to collect acoustic data. Buoys will be deployed for 3-12 months. Recovery will be accomplished by lowering a hydrophone and playing digitized codes to trigger the buoy's release.

Greater San Diego Science and Engineering Fair
JIMO was an official sponsor of this event, awarding prizes for First, Second, and Third place in both the Junior and Senior divisions. Winning projects ranged from parthenogenesis in Sea Urchins to Salinity of San Diego County estuaries and lagoons. The award winners were invited and attended the JIMO review reception, displaying their projects alongside the JIMO fellows' scientific poster session. The students enjoyed attending the event at the Birch Aquarium and interacting with JIMO scientists:

Letter Excerpt:

I was honored to have my project recognized by JIMO. Thank you for inviting me to the reception at the Birch Aquarium and presenting me with the certificate, t-shirt, and UCSD gift card. It was a privilege to present my project to you. I am very grateful to have received your recognition.
Most sincerely,
Evan Morikawa

Aquatic Adventures Bahia Program

http://www.aquaticadventures.org/bahia/

BAHIA, a partnership between Aquatic Adventures, Hoover High School as part of the City Heights Educational Collaborative, and San Diego State University, is an innovative program that draws on the region's resources to fill the gaps in the community's science education opportunities. Approximately 30 Hoover High School students (half 9th grade and half 11th grade students) are enrolled annually, beginning in 2004. Students commit to the BAHIA program by completing ten weeks of intensive coursework in marine science and ecology. Through this curriculum, students perform dissections and experiments, learn to keep a lab notebook and journal, participate in university research and field trips, and gain swimming and snorkeling skills. When the traditional school year draws to a close, the students depart for a five-week stay at the Vermillion Sea Field Station where they work on directed field research projects in Bahia de los Angeles, Mexico. Representing JIMO at this event were Bob Knox and John Hildebrand lab members.

Center for Informal Learning in Schools (CILS) presentations

The Center for Informal Learning in Schools (CILS) Fisheries ecology presentations given to students in San Francisco, Santa Cruz, and London by JIMO fellow Marc Mangel.

Marine Mammal Acoustics web site

Web site on marine mammal sounds and JIMO project developed by John Hildebrand and his group: www.cetus.ucsd.edu

Lab Tours for Greater San Diego Science & Engineering Fair Students

30-minute tour of Franks/Azam lab given to Science Fair students to provide hands-on education in a Marine Biology lab studying red tide and Lingulodinium polyedrum.

Multi-media web site on new Samoan Volcanic Seamount

The WHOI-SIO research group, including Hubert Staudigel, produced a web site and press release on the Nafanua Seamount discovery (http://earthref.org/ERESE/projects/ALIA/) in collaboration with High-Tech High School and the Birch Aquarium (SIO) to educate middle and high schools of new discoveries in science.

Public Outreach on Research and Conservation of Salmonids in Monterey Bay

In partnership with the Monterey Bay National Marine Sanctuary, Monterey Maritime Museum, NOAA NWS, and Monterey Bay Salmon and Trout Project, JIMO Fellow Pete Adams and members of SPAT participated in three events aimed at educating the public about research activities and the biology and conservation of anadromous salmonids in Monterey Bay.
- o USGS 125th Anniversary Open House, Santa Cruz, CA, September 2004
- o Currents Symposium, Monterey Bay State University, March 2005
- o USGS-NMFS Joint Symposium, Santa Cruz, CA, June 2005

COMMUNICATIONS, NETWORKING, ACADEMIC DEVELOPMENT and AWARDS

ACTIVITY TYPE	OBJECTIVE	PARTNERS
Communications		
Conference on Communications of Forecast Data	Bring together collaborators on communications efforts in North America	NOAA/OGP and Rutgers University
Special issue of Deep-Sea Research devoted to "CalCOFI: A Half Century of Physical, Chemical and Biological research in the California Current System"	Present recent research accomplishments of CalCOFI and allied programs	Edited by D. Checkley (JI),S. Bograd (NOAA) and W.S. Wooster (UW)
ARGO web site www.argo.ucsd.edu	Provide a focal point for the public and ARGO participants to find information, progress and access data	
Oral presentation at NOAA NESDIS Office of Research and Applications, May 17, 2005, Washington, D.C.	Discuss the parallel image processing environment (PIPE): Automated parallelization of satellite data analyses	NOAA National Environmental Satellite, Data, and Information Services (NESDIS)
CSRC Web site (http://csrc.ucsd.edu)	Provide on-line access to CSRC resources	
Maintenance of mail listservers for CSRC Executive Committee, CSRC Council, and general CSRC membership	Provide a convenient and recordable communications mechanism	
CSRC Semi Annual (Fall) Meeting, SIO, October 22, 2004	Semi-annual business meeting of the CSRC Coordinating Council	UCSD's CSRC Support Group
CSRC Semi Annual (Spring) Meeting, PG&E headquarters, San Francisco, May 17, 2005	Semi-annual business meeting of the CSRC Coordinating Council	Hosted for the second year by Pacific Gas & Electric
SOPAC web site (http://sopac.ucsd.edu)	Provides precise hourly orbits to the general public	International GPS Service
Meeting of the Society for Environmental Journalists, San Diego, CA, Jan. 28, 2005	Disseminate California Climate/Energy issues	
Women's Environmental Council, San Diego Branch, April 27, 2005	Disseminate California Climate/Energy issues	
NOAA Climate Day on Capital Hill, Washington DC, Jun 16, 2005	Public lecture to staff of lawmakers Clinton, Boxer, Feinstein, Murry and Issa	
Public Lecture on California Energy and Climate Issues, SIO Birch Aquarium, Sep 13, 2004	Televised on UCSD TV and the University Channel	

ACTIVITY TYPE	OBJECTIVE	PARTNERS
Networking		
CSTAR Seminar Series in Applied Theoretical Ecology	Speakers on the subject of ecology training are invited to the UCSC campus to interact with students one on one	**27 September** Ricardo Lemos, Instituto de Oceanografia - Faculdade de Ciencias da Universidade de Lisboa: Climate Change and Coastal Upwelling Ecosystems
		4 October Colin Clark, University of British Columbia: Fisheries Management–The Problem of Overcapacity
		18 October Ray Hilborn, University of Washington: Biocomplexity and fisheries sustainability
		22 November Nadav Nur, Quantitative Ecology Program, PRBO Conservation Science: Population responses of Cassin's Auklets to changes in oceanographic condition: proximate and ultimate factors
		10 January Pat Livingston, NOAA Fisheries, Alaska Fisheries Science Center: The role of multispecies and ecosystem models in a framework for assessing ecosystem impacts of fishing
		24 January Lillian Hoddeson, Department of History, University of Illinois: The problem solving styles of John Bardeen
		7 February Claudia Neuhauser, Department of Ecology, Evolution and Behavior, University of Minnesota: The role of space in trophic interactions
		28 February Hiroshi Hakoyama, National Research Institute of Fisheries Science, Yokohama, Japan: Extinction risk of a population: estimation, aggregation and model selection
		7 March Carlos Castilla-Chavez, Arizona State University: Dispersal, disease and life history evolution
		5 May Sir John Krebs FRS, Department of Zoology, University of Oxford: Risk: food fact and fantasy
		6 May Sir John Krebs FRS, Department of Zoology, University of Oxford: Science and policy—handling uncertainty

Scripps Experimental Climate Prediction Center (ECPC)	Organized 6 international workshops on the regional spectral model (RSM)	International Research Institute (IRI)
Attendance at monthly land surveyors meetings in northern (Swanson) and southern (Whitaker) California	Keep community abreast of CSRC activities	California Land Surveyors Association (CLSA)
Annual meeting of League of California Surveying Organizations, Southern Region (Helmer), Riverside, April 7, 2005	This is an important venue for highlighting CSRC accomplishments and receiving public feedback and relating our efforts to those of NGS, PBO, etc.	Riverside County Flood Control and Water Conservation District hosted the meeting
Bay Area Real-Time Meeting, Alameda County, December 15, 2004	Yehuda Bock, Don D'Onofrio and Jim Swanson attended meeting on the establishment of a real-time network in Bay Area	East Bay Regional Park District, Alameda County Surveyors Office, Contra Costa County Surveyors Office, Central Contra Costa Sanitation District, East Bay Municipal Utility District, University Of California Seismology Laboratory
California Center of Population Dedication, Buttonwillow, October 16, 2004	Don D'Onofrio represented CSRC at this dedication, and presented its role in the geodetic community and activities associated with the center of population determination	California Land Surveyors Association, NGS, Caltrans and the US Bureau of the Census.
Energy Modeling forum—Climate Change Impacts	Assessments of risks of future climate change	Dept. of Energy (DOE), Stanford University
North Pacific Acoustics Laboratory Workshop, Blaine, WA, May 12-14, 2005	Meeting with CORC collaborators at NPAL and discuss findings and application of CORC data	
NSF-Biology Seamount Research Coordination Network	Bring together all researchers working on seamounts	National Science Foundation and 30 charter members

ACTIVITY TYPE	OBJECTIVE	PARTNERS
Academic Development		
Multinational cruise of *R/V El Puma* in Gulf of California off Mazatlan to study seeps	Resulted in technology transfer between Institutions	Elva Escobar, Universidad Nacional Autonoma de Mexico (UNAM)
Steering Committee for the SEREAD Project http://www-argo.ucsd.edu	Develops teaching materials for introduction into the existing curricula of South Pacific island nations	Dean Roemmich, SIO
UCR Spatial Reference Seminar (Oct. 19-20, 2004) – Bock, Whitaker, Helmer	Annual seminar to educate professionals on CSRC procedures, Web Site	Greg Helmer, CSRC volunteer, Chair CSRC Council and Executive Committee
GPS Techniques Class (Winter Quarter, 2005) -- Whitaker	Education	UC Riverside Extension

Booth at CLSA conference in Las Vegas, March 2005	Education and outreach	California Land Surveyors Association
Annual Fresno State surveying conference, January 2005	Education and outreach	
Revelle College Freshman Honors Seminar on Climate Variability	To make young students aware of opportunities/applications in environmental science	UCSD Provost
"Perspectives on Ocean Science" public lecture at the Birch Aquarium	To instill the importance of a historical perspective on climate to the general public	Birch Aquarium, SIO
SIO "California Issues" forum: Climate and Energy in California, SIO, La Jolla	Public lecture and workshop	
"Climate Change: a challenge looming for California"	Invited article published in the Sunday "Insight" section of the San Diego Union-Tribune, Aug. 15, 2004	

AWARD	RECIPIENT	YEAR
Awards and Honors		
American Association of Museums Silver Muse Award for Educational/Interpretive Science. Awarded for "Whales: Voices of the Sea" exhibit displayed at the Aquarium of the Pacific and developed by SIO scientists. (http://www.mediaandtechnology.org/muse/2005muse_science.html)	John Hildebrand	2005
Pacific Seabird Group, Lifetime Achievement Award	George L. Hunt	2004
The Tyler Prize for Environmental Achievement	D. Charles Keeling	2005
Distinguished Visiting Professor, Universidad Nacional Autonoma de Mexico (UNAM)	Lisa Levin	2004
Appointed Academician of the Pontifical Academy of Sciences by Pope John Paul II	V. Ramanathan	2004
American Meteorological Society (AMS) Fellow	John Roads	2005
Appointed Distinguished Professor, University of California, San Diego	Richard Somerville	2004

Shown above: David Charles Keeling, winner of the distinguished Tyler Prize for Environmental Achievement in 2005.

JIMO PARTNERS AND COLLABORATORS

Alaska Fisheries Science Center (AFSC)

Atlantic Oceanographic and Meteorological Lab (AOML)

California Sea Grant

Climate Monitoring and Data Collection (CMDC)

Climate Prediction Center (CPC)

Coastal Service Center (CSC)

Department of Energy (DOE)

Environmental Technology Laboratory (ETL)

Forecast Systems Laboratory (FSL)

International Argo Community/National Ocean Partnership Program (NOPP)

Monterey Bay National Marine Sanctuary

National Aeronautics and Space Administration (NASA)

    NASA Jet Propulsion Laboratory (JPL)

    NASA REASoN CAN

    NASA SENH Program

National Climate Data Center (NCDC)

National Centers for Environmental Prediction (NCEP)

National Environmental Satellite, Data, and Information Services (NESDIS)

National Geodetic Service (NGS)

National Marine Mammal Laboratory (NMML)

National Ocean Service (NOS)

National Science Foundation (NSF)

    NSF Biology Seamount Research Coordination Network

    NSF Ecological Research Program

National Weather Service (NWS)

NOAA's Underwater Research Program (NURP)

Northwest Fisheries Science Center (NWFSC), NMFS

Office of Naval Research (ONR)

    ONR North Pacific Acoustics Laboratory (NPAL)

    ONR Southern California Channel Island region

Office of Global Program (OGP)

Office of Ocean Exploration (OE)

Olympic Coast National Marine Sanctuary (OCNMS)

Pacific Disaster Center (PDC)

Pacific Marine Environment Lab (PMEL)

SIO's Estimating the Circulation and Climate of Oceans (ECCO) Consortium

Southwest Fisheries Science Center (SWFSC), NMFS

U.S. Antarctic Marine Living Resources (AMLR)

U.S. Antarctic Research Program (USARP)

U.S. Fish and Wildlife Service (FWS)

U.S. Fire Service (USFS)

U.S. Geological Survey (USGS)

Weather & Air Quality (WAQ)

PARTNERSHIPS

Aquarium of the Pacific, Long Beach, CA

Busan University, S. Korea

California Application and Energy Projects

California Center for Ocean Science Excellence in Education (CA COSEE)

California Climate Change Center

California Coastal Salmonid Monitoring Plan

California Department of Transportation (Caltrans), Office of Land Surveys

California Department of Fish and Game (CDFG)

California Department of Water Resources

California Energy Commission

California Independent System Operator

California Polytechnic Institute (CalPoly)

California Public Utilities Commission

Center for Integrated Marine Technology (CIMT), UCSC

Centro de Investigacion Cientifica y de Educacion Superior de Ensenada (CICESE)

Centro de Previsao de Tempo e Estudos Climaticos (CPTEC), Brazil

Commercial Fishermen in the Central California Region

Commonwealth Scientific and Industrial Research Organisation (CSIRO)—Australia

Coordinated Enhanced Observing Period (CEOP) International Community

DSI Power

Fisheries Research Service (FRS), Aberdeen, Scotland

Global Energy and Water-cycle Experiment (GEWEX)

Global Fire Monitoring Center, Potsdam, Germany

Global Precipitation Climatology Centre (GPCC), Germany

Hong Kong Observatory

Investigaciones Mexicanas de la Corriente de California

International Research Institute (IRI) for Climate Prediction

International Research Programme on Climate Variability and Predictability (CLIVAR)

Massachusetts Institute of Technology (MIT), Harvard

Max Planck Institute, Hamburg, Germany

Monterey Bay Salmon & Trout Project

Moss Landing Marine Laboratories (MLML)

National Institute of Water and Atmospheric Research (NIWA), New Zealand

National Taiwan University (NTU), Taipei, Taiwan

Ocean Institute, Dana Point, California

Orange County Public Facilities and Resources Division

Pacific Gas & Electric

PacifiCorp

Pt. Reyes Bird Observatory

San Diego County Sheriffs' Department

San Diego County Department of Public Works (DPW)

San Diego Gas & Electric

San Diego Real Time GPS Network

Santa Cruz County Regional Conservation District

Santa Margarita River Ecological Reserve

Sempra Utilities

Servicio Hidrografico y Oceanografico de la Armada de Chile (SHOA)—Chile

Sierra Energy

SoCal Gas

Southern California Coastal Water Resource Project (SCCWRP)

Southern California Metropolitan Water District

Tohoku University, Japan

Union of Concerned Scientists

University of Alaska

University of California, Los Angeles (UCLA)

University of California, Santa Barbara (UCSB)

University of New England

University of Washington, Seattle

Woods Hole Oceanographic Institution (WHOI)

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REPRESENTING JIMO

EVENT	DATE / LOCATION	REPRESENTATIVE
Am. Meteor. Soc. 85th Ann. Meeting	January 9-13, San Diego, CA	CAP members, ECPC members, G. Roberts
American Geophysical Union Joint Assembly	May 23-27, 2005, New Orleans, LA	J.C. Collier, G.J. Zhang, P. Adams
Testimony given to the U.S. Senate Commerce, Science and Transportation Committee, chaired by Sen. J. McCain	Sept. 2004, DC	D. Cayan, California Applications Program (CAP)
10th Annual Community Climate System Model Workshop	June 21-23, 2005, Breckenridge, CO, USA	J. C. Collier and G. J. Zhang,
EOS, Trans. Am. Geophys. Union, Fall Meet. Suppl.	Dec 13-17, San Francisco, CA	CORC and CSRC Members
5th William R. and Lenore Mote International Symp.	November 2004, Sarasota, FL	CSTAR Members
1st Annual UCSC Graduate Research Symp.	June 2005, Santa Cruz, CA	CSTAR members
CALFED Science Conference	October 2004, Sacramento, CA	M.D. Dettinger, CAP, SPAT members
Los Angeles Department of Water and Power (briefing on Climate variability)	January 2005, Los Angeles	M.D. Dettinger, CAP
USGS/Fish and Wildlife Service workshop: "Important Challenges": planning effort for the 21st Century	May 2005	M.D. Dettinger, CAP
Annual American River Conf. (invited speaker)	April 2005, Sacramento, CA	M.D. Dettinger, CAP
American Water Works Research Assoc. Foundation Meetings (invited speaker)	November, 2004	M.D. Dettinger, CAP
Western States Water Council's Water Supply Challenges Workshop (invited speaker)	Sept. 2004, Salt Lake City, UT	M.D. Dettinger, CAP
National Academy of Sciences' Sackler Colloquium of the Role of Science in Solving the World's Emerging Water Problems (invited speaker)	October 2004, Irvine, CA	M.D. Dettinger, CAP
DBCP-XX : "Global Drifter Program"	Oct 16-19 2004, Shenoi, India	GDP-Rick Lumpkin of AOML for Global Drifter Program
DBCP-XX : "Hurricane Drifter Deployment Results"	Oct. 16-19 2004, Shenoi, India	GDP-Bill Scuba, Jan Mozel and Peter Niiler
JIMO/NORI International Workshop on the Western Pacific Circulation: "Western Pacific Circulation from Drifters and Altimeters"	Nov. 19 2004, La Jolla, CA	GDP-Peter Niiler
GODAY International Workshop: "The dynamics of ocean surface circulation studied using altimeter, Lagrangian drifter and wind data"	Nov. 2 2004, St. Petersburg, FL	GDP-Nikolai Maximenko, University of Hawaii
Ocean Observations for Climate Workshop: Invited Lecture on "Ocean Circulation Observations for Climate"	Apr. 27 2005, Silver Spring, MD	GDP-Peter Niiler
The Jet Propulsion Laboratory (JPL): Invited Lecture on "The importance of observing surface circulation of the oceans"	May 3 2005, Pasadena, CA	GDP-Peter Niiler
Acoustical Society of America Meeting	November 18, 2004, San Diego, CA	J. Hildebrand
Acoustical Society of America	May 18, 2005, Vancouver, Canada	J. Hildebrand
Environmental Consequence of Underwater Sounds (ECOUS) Workshop–ONR sponsored	March 16, 2005, Washington DC	J. Hildebrand
4th WMO Int'l Symposium on Assimilation of Observations in Meteorology and Oceanog.	April 2005, Prague, Czech Republic	I. Hoteit, B. Cornuelle, A. Kohl and D. Stammer, CORC
36th Int'l Liege Colloquium on Ocean Dynamics	Liege, Belgium	I. Hoteit, B. Cornuelle, D. Stammer and A. Kohl, CORC
16th Symp. On Global Change and Climate	January 10-14, San Diego, CA	S. F. Iacobellis and R. C. J. Somerville,

Variations, Am. Meteorol. Soc.		Improved Cloud-Radiation and Hydrologic Cycle Parameterizations for Modeling & Predicting Climate Variability
The Oceanography Society (TOS) Meeting	June 6, 2005, Paris, France	L. Levin, A. Rathburn, M. Tryon, J. Sellanes, V. Gallardo, E. Escobar, D. Gutierrez and A. Baco
IRIS/UNAVCO Meeting	June 9-11, 2005 Stevenson, Washington	K. Lindquist, Y. Bock, F. Vernon, D. Honcik and J. Eakins, CSRC
Sea Grant/NMFS Population Dynamics and Marine Resource Economics Fellows Annual Meeting, NWFSC	April 2005, Seattle, WA	Y. Lucero, CSTAR
California Water and Environmental Modeling Forum Workshop on Using Models in Endangered Species Act Recovery Planning	September 2004, Sacramento, CA	M. Mangel, CSTAR
Ecology, Evolution and Conservation Biology Colloquium	March 2005, University of Nevada, Reno, NV	M. Mangel, CSTAR
Seminar, Biology Dept., Univ. of Kentucky	April 2005, Louisville, KY	M. Mangel, CSTAR
UCSC Alumni Assoc. Meeting	May 2005, Seattle, WA	M. Mangel, CSTAR
EcoLunch Seminar, Univ. of Kentucky	April 2005, Louisville, KY	M. Mangel, CSTAR
Biology Seminar	May 2005, Univ. of Bergen, Norway	M. Mangel, CSTAR
Marine Science in Alaska: 2005 Symposium	January, 2005, Anchorage, AK	L. M. Munger
GLOBEC symposium: Climate Variability and Sub-Arctic Marine Ecosystems	16-20 May 2005, Victoria, B.C. Canada	L. M. Munger, J. A. Hildebrand, S. M. Wiggins and S. E. Moore
Yosemite Hydroclimate Workshop	October 2004, Yosemite Valley, CA	K. Redmond, CAP
California Air Resources Board (presentation on climate activities)	April 2005, Sacramento, CA	K. Redmond, CAP
AMS Applied Climate Meeting (presentation)	June 2005, Savannah, GA	K. Redmond, CAP
10th Ann. Meeting of the GHP	September 13-16, 2004, Montevideo, Uruguay	J. Roads, Experimental Climate Prediction Center
European Geophysical Union	April 24-29, 2005, Vienna, Austria	G. Roberts, CCN
Proc. 4th Int'l Implementation Planning Meeting for CEOP	February 28- March 4, 2005, Tokyo, Japan	A. Ruane, J. Roads and M. Kanamitsu, ECPC
The 8th International Workshop on Advanced Infrared Technology and Applications	September 9, 2005, Rome, Italy	J. J. Simpson, T. J. McIntire, J. S. Berg and Y. L. Tsou, participation in It INFRASTRUCTURE for the FUTURE study group
3rd International Symposium on Fish Otolith Research and Application	July 2004, Townsville, Australia	SPAT members
NOAA Fisheries Recovery Science Review Panel	Dec. 2004, Santa Cruz, CA	SPAT members
NOAA Fisheries Recovery Science Review Panel	May 2005, Seattle, WA	SPAT members
North American Benthological Society	May 2005, New Orleans, LA	SPAT members
Fisheries Society of the British Isles Annual International Conference: Comparative Biology and Interactions of Wild and Farmed Fish	July 2004, London, England	A. Stephens, CSTAR
Center for Informal Learning and Schools	August 2004, Bay Area Institute, San Francisco, CA	A. Stephens, CSTAR
Proceedings 12th Biennial Conf. of the Int. Inst. of Fisheries Economics and Trade	July 26-29, 2004, Tokyo, Japan	H. Uchida and J. Wilen, A Joint Program for Training and Research in Marine Resource Management Modeling
22nd Wakefield Symposium (Sea Lions of the World: Conservation and Research in the 21st Century)	Sep 30- Oct 3, Anchorage, AK	N. Wolf, CSTAR
AMS Meeting, 13th Conf. Interactions of the Sea and Atmos.	August 9-13 2004, Portland, ME	E. Yulaeva and N. Schneider

PUBLICATIONS

Published Papers

Alfaro, E. J., A. Gershunov, D. R. Cayan, A. Steinemann, D. W. Pierce, and T. P. Barnett. A method for prediction of California summer air surface temperature. *EOS*. 85:553-557. (2004).

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PUBLICATION SUMMARY

	JIMO Lead Author				NOAA Lead Author				Other Lead Author			
	2001-02	2002-03	2003-04	2004-05	2001-02	2002-03	2003-04	2004-05	2001-02	2002-03	2003-04	2004-05
Peer Reviewed	23	24	76	89	2	4	20	20	30	32	30	57
Non Peer Reviewed	56	40	52	62	0	0	12	19	61	41	28	39
	79	64	128	151	2	4	32	39	91	73	58	96

ACRONYMS

AFSC	NOAA/Alaska Fisheries Science Center
AMLR	Antarctic Marine Living Resources Program
AOML	NOAA/Atlantic Oceanographic and Meteorological Lab
CA COSEE	California Center for Ocean Science Excellence in Education
CALFED	California Bay-Delta Program
CalPoly	California Polytechnic Institute
Caltrans	California Department of Transportation
CAP	California Applications Program
CDFG	California Department of Fish and Game
CDWR	California Department of Water Resources
CEC	California Energy Commission
CEFA	Climate, Ecosystem and Fire Applications
CEFAS	Centre for Environmental Fisheries and Aquaculture Science, UK
CEOP	Coordinated Enhanced Observing Period
CIASTA	Cooperative Institute for Atmospheric Sciences and Terrestrial Applications, Nevada
CICAR	Cooperative Institute for Climate Applications and Research, Palisades, New York
CICOR	Cooperative Institute for Climate and Ocean Research, Woods Hole, Massachusetts
CICS	Cooperative Institute for Climate Science, Princeton, New Jersey
CIFAR	Cooperative Institute for Arctic Research, Fairbanks, Alaska
CILER	Cooperative Institute for Limnology and Ecosystems Research, Ann Arbor, Michigan
CIMAS	Cooperative Institute for Marine and Atmospheric Studies, Miami, Florida
CIMMS	Cooperative Institute for Mesoscale Meteorological Studies, Norman, Oklahoma
CIMSS	Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin, Madison
CIMT	Center for Integrated Marine Technology, UCSC
CIRA	Cooperative Institute for Research in the Atmosphere
CIRES	Cooperative Institute for Research in Environmental Sciences
CLIMAS	Climate Assessment for the Southwest
CLIVAR	International Research Programme on Climate Variability and Predictability
CPTEC	Centro de Previsao de Tempo e Estudos Climaticos, Brazil
CPUC	California Public Utilities Commission
CSIRO	Commonwealth Scientific and Industrial Research Organisation--Australia
DOE	U.S. Department of Energy

DRI	Desert Research Institute
ECCO	SIO's Estimating the Circulation and Climate of Oceans Consortium
ENSO	El Nino and Southern Oscillation
FWS	U.S. Fish and Wildlife Service
GEWEX	Global Energy and Water-cycle Experiment
GFDL	NOAA/Geophysical Fluid Dynamics Laboratory
GODAE	Global Ocean Data Assimilation Experiment
GPCC	Global Precipitation Climatology Centre, Germany
GPS	Global Positioning System
HRC	Hydrologic Research Center, San Diego, CA
IfM	Institute of Oceanography, Univ. of Hamburg, Germany
IRI	International Research Institute for Climate Prediction
JIMAR	Joint Institute for Marine and Atmospheric Research
JIMO	Joint Institute for Marine Observations
JISAO	Joint Institute for the Study of Atmosphere and Ocean
JPL	Jet Propulsion Laboratory, NASA
MBARI	Monterey Bay Aquarium Research Institute
MIT	Massachusetts Institute of Technology, Harvard
MLML	Moss Landing Marine Laboratories, Moss Landing, CA
MPL	Marine Physical Laboratory, SIO, UCSD
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	NOAA/National Centers for Environmental Predictions
NESDIS	NOAA/National Environmental Satellite, Data, and Information Services
NIWA	National Institute of Water and Atmospheric Research, New Zealand
NMFS	NOAA/National Marine Fisheries Service
NMML	National Marine Mammal Laboratory
NOPP	National Ocean Partnership Program
NOS	NOAA/National Ocean Service
NPAL	North Pacific Acoustics Laboratory, ONR
NSF	National Science Foundation
NTU	National Taiwan University, Taipei, Taiwan
NTU	Nephelometric Turbidity Unit
NURP	NOAA's Underwater Research Program
NWFSC	NOAA/Northwest Fisheries Science Center, NMFS

NWS	NOAA/National Weather Service
OAR	NOAA/Ocean and Atmospheric Research
OE	NOAA/Office of Ocean Exploration
OGP	NOAA/Office of Global Programs
ONR	Office of Naval Research
ORA	NOAA/Office of Research and Applications
OCNMS	NOAA/Olympic Coast National Marine Sanctuary
PG&E	Pacific Gas & Electric
PMEL	NOAA/Pacific Marine Environment Lab (PMEL)
PRBO	Pt. Reyes Bird Observatory
R/V	Research Vessel
RISA	NOAA/Regional Integrated Sciences and Assessments
SCCWRP	Southern California Coastal Water Resource Project
SDG&E	San Diego Gas & Electric
SEFSC	NOAA/Southeast Fisheries Science Center, Panama City, FL
SHOA	Servicio Hidrografico y Oceanografico de la Armada de Chile--Chile
SIO	Scripps Institution of Oceanography, UCSD
SPAT	Salmon Population Analysis Team, UCSC
SST	Sea surface temperature
SUNY	State University of New York
SWFSC	NOAA/Southwest Fisheries Science Center, NMFS
UAF	University of Alaska, Fairbanks
UC	University of California
UCD	University of California, Davis
UCLA	University of California, Los Angeles
UCSB	University of California, Santa Barbara
UCSC	University of California, Santa Cruz
UCSD	University of California, San Diego
UNAM	Universidad Nacional Autonoma de Mexico
USARP	U.S. Antarctic Research Program
USC	University of Southern California
USFS	U.S. Fire Service
USGS	U.S. Geological Survey
UW	University of Washington, Seattle
VOS	Voluntary Observing Ship

WAQ	NOAA/Weather & Air Quality Research
WHOI	Woods Hole Oceanographic Institution
WOCE	World Ocean Circulation Experiment
WRCC	Western Regional Climate Center, Desert Research Institute (DRI)
XBT	Expendable Bathythermograph